THE STRUCTURE OF CRYSTALS

Supplement for 1930-1934 to the
SECOND EDITION

BY

RALPH W. G. WYCKOFF

American Chemical Society
Monograph Series

BOOK DEPARTMENT

REINHOLD PUBLISHING CORPORATION
Successor to
THE CHEMICAL CATALOG COMPANY, INC.
330 WEST FORTY-SECOND STREET, NEW YORK, U.S.A.
1935

THE HADDON CRAFTSMEN, INC.
CAMDEN, N. J.

Preface

This supplement is a summary of new X-ray structure determinations published during the past four years. As such it follows strictly the form used in Part II of the second edition of "The Structure of Crystals" and aims to include all new studies that lead at least to cell dimensions. In order to facilitate comparison, the figure numbers and paragraph designations are continuations of those in the book. As before, reference numbers, with the year in bold-face, apply to the appended bibliography. The grouping of compounds is identical with that previously used except that in the chapter covering the type RX_3 a separate table has been created for crystals of the composition $R_x(MX_2)_y$.

The writer is indebted to R. B. Corey and K. Pestrecov for much help in making the illustrations and to A. A. Murtland for assistance in preparing the bibliography.

Rockefeller Institute for Medical Research
New York, N. Y.
February, 1935

Table of Contents

The chapters in this supplement are all lettered A and correspond in content to the similarly numbered chapters in Part II of the book—second edition.

Chapter XA. Structures of the Elements

Most of the new data of Table I are accurate determinations of the cell dimensions of the metallic elements. For some metals which can easily be prepared in a state of great chemical purity the edge lengths of the units are now known with an accuracy of 0.0002 to 0.0003 A. The error for most elements is, however, about ten times greater. Spacings to the fourth decimal place have real significance only if the purity is precisely known, if the sample is sufficiently outgassed and otherwise prepared for measurement and if the temperature is determined. It is not always possible to be sure from the published data that all these conditions have been properly met; the accuracy limits stated in Table I are therefore for the most part those set by the investigators themselves.

New information about the atomic arrangements in elements are recorded in the paragraphs that follow.

(*v*) In place of the previously described tetragonal structure for **gallium** there has recently been given an orthorhombic (pseudo-tetragonal) arrangement based on V_h^{18} and having its eight atoms in the special positions:

$$
\begin{aligned}
&\text{(f)}\ \tfrac{1}{4}uv;\ \tfrac{3}{4},\ u,\ \tfrac{1}{2}-v;\ \tfrac{3}{4},\ u+\tfrac{1}{2},\ v;\ \tfrac{1}{4},\ u+\tfrac{1}{2},\ \tfrac{1}{2}-v;\\
&\quad\ \tfrac{1}{4}\bar{u}\bar{v};\ \tfrac{3}{4},\ \bar{u},\ v+\tfrac{1}{2};\ \tfrac{3}{4},\ \tfrac{1}{2}-u,\ \bar{v};\ \tfrac{1}{4},\ \tfrac{1}{2}-u,\ v+\tfrac{1}{2}
\end{aligned}
$$

with $u=0.159$, $v=0.080$. As is evident from Figure 275 (drawn for comparison with Figure 168) this arrangement is very different from the earlier one.

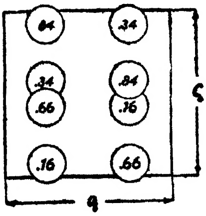
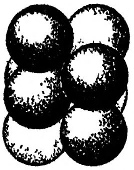


FIG. 275*a*.—(*left*) The unit cell of the new orthorhombic arrangement found for metallic gallium as projected on its b-face.

FIG. 275*b*.—(*right*) A packing drawing of the gallium atoms shown in *a*.



(*w*) The rhombohedral structure of **mercury** has recently been confirmed by single crystal measurements at $-50°$ C. At the same time it is shown that the diffraction data upon which a false hexagonal arrangement was based (**1922**, 1) apparently were a mixture of the lines of mercury and of solid CO_2.

(*x*) Three recent determinations agree with the original in giving **indium** a face-centered tetragonal arrangement with atoms at 000; $\frac{1}{2}\frac{1}{2}0$; $\frac{1}{2}0\frac{1}{2}$; $0\frac{1}{2}\frac{1}{2}$.

(*y*) The X-ray patterns from the β-form of **nitrogen** are thought to indicate that it is a close-packed assemblage of spherical (rotating) N_2 molecules. The parameter chosen for the center of gravity of these molecules is 0.22.

(*z*) Hexagonal **nickel** prepared by a glow discharge in N_2 has the dimensions stated in the table; prepared in H_2 its unit is larger: $a_o = 2.66$ A, $c_o = 4.29$ A. It reverts to cubic nickel if heated to 300° C.

(*aa*) This modification of **tungsten**, said to be obtained by electrolyses under various conditions, is thought to have 8 atoms in its unit. The atoms have been placed at (2a) and (6g) (of **1930**, 352) though no intensity data are given in support of this assignment.

(*ab*) The recorded unit cube of α-**rhodium** is considered to contain 48 atoms. This modification is produced by the reduction of rhodium salts. mixed with the usual form it is also said to result from electrolytic reduction;

(*ac*) Plastic **sulfur** is rubber-like in that it crystallizes on stretching. The monoclinic unit recorded in the table contains 112 atoms; its space group is given as C_{2h}^2. As monoclinic sulfur (either stretched or not) ages, the diffraction lines of the orthorhombic form gradually appear.

(*ad*) The monoclinic cell of α-**Se** contains 32 atoms; its space group is reported to be C_{2h}^2. Crystals of a solid solution of selenium and sulfur (55.2 wt. % Se), which presumably are isomorphous with a second modification of monoclinic Se, have been assigned a unit different from that of the β-Se reported in the table. The unit of this mixed crystal has $a_o =$ 8.48 A, $b_o = 13.34$ A, $c_o = 8.33$ A, $\beta = 67°30'$.

(*ae*) The two **uranium** atoms in the centered unit having the dimensions of the table are said to be at 000; $0\frac{1}{2}\frac{1}{2}$. Another determination has made uranium body-centered cubic with $a_o = 3.43$ A (**1930**, 424).

(*af*) A second form of **beryllium** is reported to be present to the extent of about 10% in samples which have been heated for some time in vacuo at 600°—800° C. It is described as hexagonal with $a_o = 7.1$ A, $c_o = 10.8$ A and with ca 60 atoms in this unit cell (**1933**, 224).

(*ag*) Electrodeposition at high p_H yields β-**cobalt**, at low p_H a mixture of β and α forms (**1932**, 262). The β-cobalt becomes cubic above 450° C without change in crystal boundaries; it reverts only on cold rolling or through high temperature annealing (**1932**, 463).

TABLE I. THE CRYSTAL STRUCTURES OF THE ELEMENTS

Element	*Crystal system*	*Type of structure*	a_0	c_0 *or* α	*References*
Ag Silver	Cubic	F.c. (*a*)	4.0772± 0.0002[1]		**1932**, 348; **1933**, 342; **1934**, 199.
Al Aluminum	Cubic	F.c. (*a*)[2]	4.0406± 0.0002		**1931**, 8; **1932**, 336, 348; **1933**, 342, 420.
As Arsenic	Hexagonal	As (*e*)			**1934**, 295.
Au Gold	Cubic	F.c. (*a*)	4.0699± 0.0003[3]		**1932**, 348; **1933**, 342, 343; **1934**, 124, 357.
Be Beryllium	Hexagonal	C.p. (*b*), (*af*)	2.2680± 0.0002	3.5942± 0.0003	**1932**, 329; **1933**, 224, 319.
Bi[4] Bismuth	Hexagonal	As (*c*)			**1930**, 369, 434; **1931**, 420; **1932**, 162.
C[5] Graphite	Hexagonal	(*h*)			**1931**, 208.
β-Ca (>450° C) Calcium	Hexagonal	(*ah*)	3.98	6.52	**1933**, 121, 156; **1934**, 93.
Cb Columbium	Cubic	B.c. (*c*)	3.294± 0.001[6]		**1931**, 323, 324; **1932**, 371; **1934**, 43.
Cd Cadmium	Hexagonal	C.p. (*b*)	2.9736± 0.0005	5.6058± 0.0005[7]	**1931**, 238; **1932**, 428a.
α-Ce Cerium	Cubic	F.c. (*a*)	5.143± 0.004		**1932**, 372.
β-Co Cobalt		(*ag*)			**1932**, 262.
α-Cr Chromium	Cubic	B.c. (*c*)	2.8787		**1931**, 367a; **1932**, 369; **1934**, 125.
Cu Copper	Cubic	F.c. (*a*)	3.6077± 0.0002[8]		**1932**, 348; **1933**, 328, 342; **1934**, 357.
α-Fe Iron	Cubic[9]	B.c. (*c*)	2.8607± 0.0002		**1930**, 439; **1931**, 16; **1932**, 62, 336, 369; **1933**, 128, 342; **1934**, 124, 137.

[1] At 600° C, a_0=4.1276 A (**1934**, 199).

[2] There is no allotropic change up to 600° C (**1931**, 8; **1933**, 420).

[3] At 475° C, a_0=4.1010 A.

[4] The thermal expansion from room temperature to the melting point has been carefully measured by X-ray means (**1931**, 127; **1932**, 163; **1934**, 120, 121a).

[5] Photographs of incandescent electrodes show that expansion is all normal to the basal plane.

[6] From a very ductile preparation of Cb made by thermal decomposition of $CbCl_5$ in vacuo. Other a_0's are ca 0.01 A larger.

[7] The other precision measurement (**1931**, 238) gives lower values: a_0=2.9724, c_0=5.6042.

[8] At 475° C, a_0=3.6514 A.

[9] Measurements have been made up to 1100° C (**1930**, 439; **1933**, 128; **1934**, 137).

Element	*Crystal system*	*Type of structure*	a_0	c_0 or α	*References*
Ga Gallium	Ortho-rhombic	(*j*), (*v*)	4.506	4.506 $b_0=7.642$	1932, 282; 1933, 281.
Hg Mercury	Hexagonal	(*k*), (*w*)	2.999	70°32′ at −46° C	1929, 218; 1932, 209; 1933, 321.
In Indium	Tetragonal	(*m*), (*x*)	4.583	4.936	1932, 134; 1933, 429, 527.
Ir Iridium	Cubic	F.c. (*a*)	3.8312± 0.0005		1932, 348; 1933, 342.
Kr Krypton	Cubic[1]	F.c. (*a*)	5.69 at 88° K		1930, 428; 1932, 392.
α-La Lanthanum	Hexagonal	C.p. (*b*)	3.75	6.06	1930, 425; 1932, 372.
β-La[2] Lanthanum	Cubic	F.c. (*a*)	5.296		1933, 528; 1934, 233.
Mg Magnesium	Hexagonal	C.p. (*b*)	3.2022± 0.0002	5.1991± 0.0004	1932, 428a.
Mn (α, β, γ) Manganese					1931, 411.
Mo Molybdenum	Cubic	B.c. (*c*)	3.140± 0.001		1932, 348.
α-N_2 (<35° K) Nitrogen	Cubic	(*o*)	5.67		1932, 391.
β-N_2 (>35° K) Nitrogen	Hexagonal	(*y*)	4.039	6.670	1932, 391, 456; 1934, 272.
Nd Neodymium	Hexagonal	C.p. (*b*)	3.65_7	5.88	1932, 372.
α-Ni Nickel	Cubic	F.c. (*a*)	3.5175[3]		1931, 60; 1932, 62, 348; 1934, 122, 125, 198.
β-Ni Nickel	Hexagonal	C.p. (*b*), (*z*)	2.60	4.15	1931, 60.
O_2 Oxygen	Ortho-rhombic				1932, 316, 391.
Os Osmium	Hexagonal	C.p. (*b*)	2.716	4.331	1932, 434.
Pb Lead	Cubic	F.c. (*a*)	4.9396± 0.0003		1931, 420; 1932, 120, 348; 1933, 327, 342; 1934, 192.
Pd Palladium	Cubic	F.c. (*a*)	3.8823_8		1931, 427; 1932, 348; 1933, 342, 343.

---

[1] There is no X-ray evidence for a structural transition.

[2] This form appears as a surface layer on the α-material after vacuum annealing at 350° for several days.

[3] Another determination, on 99.88% Ni, gives $a_0=3.5143$ A.

Element	*Crystal system*	*Type of structure*	a_0	c_0 or α	*References*
Pr Praseodymium	Hexagonal	C.p. (*b*)	3.657	5.924	1932, 93, 390.
Pt Platinum	Cubic[1]	F.c. (*a*)	3.9161± 0.0003		1933, 342, 343; 1934, 199.
Re Rhenium	Hexagonal	C.p. (*b*)	2.7553± 0.0004	4.4493± 0.0003	1931, 3, 4, 305; 1932, 428a.
α-Rh Rhodium	Cubic	(*ab*)	9.211		1931, 225, 226.
β-Rh Rhodium	Cubic	B.c. (*c*)	3.7955_9		1931, 225; 1932, 348; 1933, 342, 343.
S Sulfur (Plastic form stretched)	Monoclinic	(*ac*)	26.4 $b_0=9.26$,	12.32 $\beta=79°15'$	1930, 119a; 1931, 448; 1932, 447; 1934, 175.
Sb Antimony	Hexagonal	As (*e*)[2]			1932, 263.
Se (α-form) Selenium	Monoclinic	(*ad*)	8.992 $b_0=8.973$,	11.52 $\beta=91°34'$	1931, 152, 153; 1934, 136.
Se (β-form) Selenium	Monoclinic	(*ad*)	12.74 $b_0=8.04$,	9.25 $\beta=93°4'$	1934, 136.
Sn (white) Tin	Tetragonal	(*s*)	5.8194± 0.0003	3.1753± 0.0009	1932, 428a; 1933, 429.
Ta Tantalum	Cubic	B.c. (*c*)	3.296[3]		1932, 348, 371; 1934, 43.
Tl (α, β) Thallium					1931, 411.
U Uranium	Monoclinic	(*ae*)	2.829 $b_0=4.887$,	3.308 $\beta=63°26'$	1930, 424; 1933, 507.
W Tungsten	Cubic	B.c. (*c*)	3.1589		1932, 348; 1933, 318; 1934, 187.
W (second form) Tungsten	Cubic	(*aa*)	5.038		1933, 318.
X Xenon	Cubic	F.c. (*a*)	6.24 at 88° K		1930, 220a; 1932, 392.
Y Yttrium	Hexagonal	C.p. (*b*)	3.66_3	5.81_4	1932, 370.
Zn[4] Zinc	Hexagonal	C.p. (*b*)	2.6589	4.9349	1932, 52, 428a; 1933, 337, 339, 493; 1934, 199.
Zr Zirconium	Cubic	B.c. (*c*)	3.61 near 862° C		1932, 84, 85.

---

[1] At 600° C, $a_0=3.9383$ A.

[2] "Explosive" Sb is amorphous; it becomes crystalline on exploding.

[3] This measurement was made upon a very ductile sample prepared by the thermal dissociation of $TaCl_5$ in vacuo. Results on other material are higher (3.311 A in 1932, 348).

[4] At 415° C, a_0 = 2.6792 A, c_0 = 5.0481 A. There is no structural change up to the melting point.

(*ah*) The evidence concerning the structure of β-**calcium** (stable above 450° C) was at first contradictory. It is now known that if the metal is pure it is hexagonal close-packed (*b*); if impure it may be either hexagonal or body-centered cubic (*c*) with a_0=ca 4.33 A.

Alloys

A bibliography of new papers describing X-ray measurements on alloy systems is contained in Table II. The structures that occur in metallic systems are of three kinds: (1) solid solutions of one metal in the lattice of another, (2) definite chemical compounds with atoms combined together in stoichiometric proportions, (3) phases with atoms in fixed geometric array but with compositions that can vary over wide limits. Many examples of the second type are described in succeeding chapters but no attempt has been made to summarize the data about structures (1) and (3).

A few non-metallic compounds such as pyrrhotite (FeS) can contain an excess of one or the other of their atomic components; similar compounds, which we often erroneously, from a structural standpoint, describe as being capable of taking one or both of their constituents into solid solution, are common amongst intermetallic compounds. Within recent years another kind of intermetallic compound, the so-called superlattice compound, has become familiar. A superlattice is a relatively complicated atomic arrangement which arises, as an equilibrium state, through the prolonged annealing of an alloy of stoichiometric atomic composition. Such alloys before annealing are usually solid solutions having their atoms in haphazard distribution. Especially simple superlattices are illustrated by the compounds AuCu and $AuCu_3$; Sb_2Tl_7 is a more complicated example.

TABLE II. BIBLIOGRAPHY OF ALLOY SYSTEMS

Alloy system	*References*
Ag-Al	**1932**, 364; **1933**, 2, 29; **1934**, 1, 139.
Ag-As	**1931**, 66.
Ag-Au	**1933**, 116, 283, 502.
Ag-Bi	**1931**, 66.
Ag-Cd	**1931**, 436; **1932**, 430; **1933**, 450.
Ag-Cu	**1930**, 3a; **1931**, 96, 418; **1932**, 306, 477; **1933**, 414, 505.
Ag-Hg	**1931**, 313, 367; **1933**, 494.
Ag-Li	**1931**, 348.
Ag-Pd	**1931**, 427; **1933**, 275.
Ag-Rh	**1933**, 118.
Ag-Sb	**1931**, 66.
Ag-Sn	**1931**, 326.
Ag-Zn	**1932**, 426, 465; **1933**, 341.
Al-Au	**1931**, 244.
Al-Co	**1931**, 105.
Al-Cu	**1931**, 334, 365; **1933**, 328, 357, 358, 436, 447, 546; **1934**, 211, 282.
Al-Fe	**1932**, 63, 64; **1933**, 334; **1934**, 313, 313a.
Al-Li	**1931**, 348.
Al-Mg	**1931**, 396; **1932**, 407; **1933**, 414; **1934**, 238a, 340.
Al-Mn	**1931**, 52.
Al-Ti	**1931**, 114.

Alloy system	*References*
Al-Zn	**1932**, 148, 313, 409, 415; **1934**, 197, 351.
As-Cu	**1929**, 205a, 205b.
As-Sn	**1934**, 295.
Au-Cd	**1932**, 442.
Au-Cu	**1931**, 366, 386; **1932**, 178; **1933**, 419; **1934**, 85a, 357.
Au-Fe	**1934**, 124.
Au-Mn	**1934**, 40.
Au-Pd	**1931**, 427; **1934**, 181.
Au-Pt	**1931**, 428.
Au-Rh	**1933**, 118.
Au-Sb	**1931**, 326; **1932**, 58.
Au-Sn	**1931**, 426; **1932**, 58.
B-Co	**1933**, 47.
B-Fe	**1933**, 47.
B-Ni	**1933**, 47.
Be-Cu	**1933**, 464.
Bi-Pb	**1931**, 420; **1932**, 246; **1934**, 82.
Bi-Sb	**1932**, 59; **1934**, 76.
Bi-Se	**1930**, 434.
Bi-Sn	**1931**, 420; **1932**, 246.
Bi-Tl	**1931**, 411; **1934**, 193.
C-Cr	**1930**, 455; **1931**, 468; **1932**, 197; **1933**, 401.
C-Fe	**1931**, 339, 340, 341, 414; **1932**, 225, 281, 474; **1933**, 128, 325; **1934**, 44, 97, 98, 259, 354.
C-Ni	**1931**, 509; **1933**, 415.
Cd-Cu	**1931**, 51; **1933**, 338.
Cd-Hg	**1932**, 438.
Cd-Li	**1933**, 27; **1934**, 11, 310.
Cd-Mg	**1930**, 72a.
Cd-Ni	**1931**, 105.
Cd-Pt	**1931**, 371.
Cd-Sb	**1930**, 379; **1932**, 1; **1933**, 167.
Cd-Sn	**1931**, 295.
Cd-Zn	**1932**, 52.
Ce-H_2	**1934**, 233.
Co-Mn	**1934**, 137.
Co-W	**1932**, 4; **1933**, 459.
Co-Zn	**1930**, 454; **1931**, 105; **1932**, 353.
Cr-Fe	**1931**, 16, 367a; **1932**, 369; **1933**, 196.
Cr-Ni	**1930**, 376; **1934**, 125.
Cu-Fe	**1932**, 95.
Cu-Li	**1930**, 247a.

Alloy system	*References*
Cu-Mg	**1934**, 242.
Cu-Mn	**1931**, 411.
Cu-Ni	**1931**, 474; **1934**, 198.
Cu-Pd	**1932**, 292.
Cu-Si	**1931**, 19, 389.
Cu-Sn	**1927**, 313; **1932**, 94, 229, 422, 426; **1933**, 253, 268; **1934**, 39, 118.
Cu-Zn	**1930**, 370; **1931**, 51; **1932**, 264, 268, 349, 350, 432, 465; **1933**, 141, 168, 339, 340; **1934**, 2, 335, 349.
Fe-H_2	**1933**, 501.
Fe-Hg	**1932**, 77.
Fe-Mn	**1930**, 388; **1931**, 125, 342, 406; **1933**, 486.
Fe-N	**1931**, 69; **1933**, 324, 510; **1934**, 44.
Fe-Ni	**1931**, 358; **1932**, 234; **1933**, 76; **1934**, 67.
Fe-Si	**1933**, 516.
Fe-Sn	**1933**, 125.
Fe-V	**1930**, 456; **1934**, 148.
Fe-W	**1931**, 343; **1932**, 435.
Fe-Zn	**1931**, 105.
H_2-La	**1934**, 233.
H_2-Pd	**1933**, 274, 384.
H_2-Ta	**1931**, 144; **1934**, 212.
H_2-Ti	**1931**, 144.
H_2-V	**1931**, 144.
H_2-Zr	**1931**, 144.
Hg-Ni	**1932**, 77.
Hg-Sn	**1933**, 439.
Ir-Os	**1932**, 434.
Li-Sn	**1932**, 20.
Mg-Mn	**1931**, 397.
Mg-Zn	**1932**, 407; **1933**, 238a, 414, 465.
Mn-N	**1933**, 411.
Mn-Si	**1933**, 58; **1934**, 337.
Mn-Zn	**1930**, 435; **1931**, 346; **1932**, 353.
Mo-Ni	**1934**, 137.

Alloy system	*References*
Na-Pb	**1933**, 451.
Na-Tl	**1932**, 500.
Ni-Zn	**1930**, 454; **1931**, 105; **1932**, 200; **1933**, 85; **1934**, 258.
Pb-Sb	**1933**, 327.
Pb-Sn	**1933**, 327.
Pb-Tl	**1931**, 411; **1934**, 192.
Pd-Zn	**1931**, 105.
Pt-Zn	**1931**, 105.
Rh-Zn	**1931**, 105.
Sb-Sn	**1931**, 49, 224; **1933**, 425.
Sb-Tl	**1931**, 411; **1934**, 180.
Sb-Zn	**1933**, 167.
Sn-Tl	**1931**, 411; **1933**, 215.
Ag-Cu-Ni	**1934**, 210.
Ag-H_2-Pd	**1930**, 237a; **1933**, 275.

Alloy system	*References*
Al-C-Fe	**1934**, 341.
Al-Cr-Fe	**1932**, 399.
Al-Cu-Mn	**1933**, 192, 193; **1934**, 26, 107.
Al-Fe-N	**1934**, 190.
Au-H_2-Pd	**1934**, 181.
Bi-S-Te	**1933**, 142.
C-Co-Fe	**1932**, 451.
C-Cr-Fe	**1931**, 468; **1932**, 475.
C-Cr-Ni	**1934**, 248.
C-Fe-Mn	**1932**, 15; **1934**, 65.
C-Fe-W	**1931**, 343.
Co-Fe-Mn	**1933**, 263; **1934**, 137.
Fe-Ni-V	**1934**, 148.
Fe-P-Si	**1933**, 401.
Al-C-Cr-Mo	**1932**, 230.

Chapter XIA. Structures of the Type RX

(*ac*) For some time there was debate as to whether the rhombohedral unit of **AgCN** contains one or two molecules and whether the correct space group is C_{3v}^5 or C_{3v}^6. A recent recalculation proves that the cell of Table I is monomolecular with C_{3v}^5 as space group and that the atoms are all on trigonal axes with the coordinates (a) uuu. Parameters have not been determined.

AgBr and AgCN form cubic solid solutions; by extrapolation from measurements on them, it can be concluded that cubic AgCN would have $a_0 = 5.69$ A if it were stable.

(*ad*) The low temperature modification of **AuCd**, stable at room temperature, has been assigned a distorted CsCl structure based on the orthorhombic space group V_h^5. The two molecules in its unit have atoms in the positions:

Cd: (e) $0u\frac{1}{4}; 0\bar{u}\frac{3}{4}$ with $u = \text{ca } \frac{5}{16}$ [or 000; $0\frac{5}{8}\frac{1}{2}$]
Au: (f) $\frac{1}{2}v\frac{1}{4}; \frac{1}{2}\bar{v}\frac{3}{4}$ with $v = \text{ca } \frac{13}{16}$ [or $\frac{1}{2}\frac{1}{2}0; \frac{1}{2}\frac{1}{8}\frac{1}{2}$].

(*ae*) The data on **CdLi** are contradictory. One determination gives it the cubic body-centered CsCl structure (*a*) with $a_0 = 3.32$ A; the other assigns to it the NaTl superstructure [(*ao*), below] with $a_0 = 6.687$ A.

(*af*) No diffraction lines have been found to give **CsCN** a unit larger than the one-molecule cell. The available experimental data thus indicate that in this cyanide, as in the other alkali cyanides, the CN group functions geometrically as a single atom.

(*ag*) It has recently been concluded that the triclinic symmetry previously assigned to **CuO** is unnecessarily low. The proposed arrangement, developed from C_{2h}^6, has atoms in the following positions:

Cu: (c) $\frac{1}{4}\frac{1}{4}0; \frac{3}{4}\frac{1}{4}\frac{1}{2}; \frac{3}{4}\frac{3}{4}0; \frac{1}{4}\frac{3}{4}\frac{1}{2}$
O: (e) $0u\frac{1}{4}; 0\bar{u}\frac{3}{4}; \frac{1}{2}, u+\frac{1}{2}, \frac{1}{4}; \frac{1}{2}, \frac{1}{2}-u, \frac{3}{4}$ with $u = 0.08$.

(*ah*) A new structure, based on photographic data, has been proposed for covellite, **CuS**. It differs from the earlier one (*q*) mainly in transferring the two sulfur atoms, which were in (a), to the coördinates (c) $\frac{1}{3}\frac{2}{3}\frac{1}{4}$;

TABLE I. THE CRYSTAL STRUCTURES OF THE COMPOUNDS RX

Substance	*Symmetry*	*Structure type*	a_0	c_0 or α	*References*
AgCN	Hexagonal	(*k*), (*ac*)	3.88	101°11′	**1933**, 317; **1934**, 288.
AgI	Hexagonal	ZnO (*d*)[1]	4.580	7.494	**1931**, 46; **1934**, 141.
AgI (low)	Cubic[2]	ZnS (*c*)	6.473		**1931**, 46; **1934**, 141.
AgI (high)	Cubic	(*aw*)	5.034		**1931**, 46; **1934**, 257.
AgLi	Cubic	CsCl (*a*)	3.168		**1930**, 247; **1931**, 348; **1933**, 523.
AlLi	Cubic		3.23		**1931**, 348.
AlNd	Cubic	CsCl (*a*)	3.73		**1934**, 255.
AuCd (low)	Ortho-rhombic	(*ad*)	3.144 b_0=4.851	4.745	**1932**, 341.
AuCd (high)	Cubic	CsCl (*a*)	3.34 at 400° C		**1932**, 341.
AuSn	Hexagonal	NiAs (*e*)	4.314	5.512	**1931**, 426; **1932**, 58; **1933**, 223.
BaNH	Cubic	NaCl (*b*)	5.84		**1934**, 103.
BaO	Cubic	NaCl (*b*)	5.523		**1933**, 80.
β-CO	Hexagonal	(*at*)	4.11	6.79	**1934**, 272.
CaNH	Cubic	NaCl (*b*)	5.006		**1933**, 137; **1934**, 103.
CaTl	Cubic	CsCl (*a*)	3.847		**1933**, 523.
CdLi	Cubic	(*ae*)	[6.687]		**1933**, 27, 523.
CdO	Cubic	NaCl (*b*)	4.689		**1931**, 272; **1933**, 158.
CdSb	Ortho-rhombic	CdSb (*n*)[3]			**1930**, 379; **1932**, 1.
CoS	Hexagonal	NiAs (*e*)	3.38	5.20	**1932**, 90.
CsCN	Cubic	CsCl (*a*), (*af*)	4.25		**1931**, 319.
CsCl (low)	Cubic	CsCl (*a*)	4.20 at ca 450° C		**1934**, 286.
CsCl (high, >456° C)	Cubic	NaCl (*b*)	7.10		**1933**, 485; **1934**, 286.
CsHS	Cubic	CsCl (*a*)	4.29		**1934**, 287.
CuF	Cubic	ZnS (*c*)	4.25_5		**1933**, 122.
CuO (Tenorite)	Monoclinic	(*o*), (*ag*)	4.66 b_0=3.40, β=99°30′	5.09	**1933**, 479.
CuS (Covellite)	Hexagonal	(*q*), (*ah*)	3.76	16.26	**1930**, 371; **1932**, 342.
(Cu, Fe, Mo, Sn)$_4$(S, As, Te)$_{3\text{-}4}$ (Colusite)	Cubic	ZnS (*c*)	5.304		**1933**, 517.
FeO	Cubic	NaCl (*b*), (*ai*), (*ax*)	4.33_2		**1933**, 234, 235; **1934**, 77.
FeS	Hexagonal	NiAs (*e*), (*aj*)			**1932**, 253; **1933**, 162, 165; **1934**, 176.
FeSi	Cubic	(*t*)			**1930**, 340a.

[1] $u = 0.37_1$.

[2] Precipitates with excess of Ag ions.

[3] According to one analysis there are two forms of CdSb, both hexagonal with identical unit cells (1930, 379).

Substance	*Symmetry*	*Structure type*	a_0	c_0 or α	*References*
GeS	Orthorhombic	(*ak*)	4.29	3.64 $b_0=10.42$	**1932**, 489.
HBr (low)	Orthorhombic (pseudo-cubic)	(*al*)	5.555	6.063 $b_0=5.64$	**1931**, 316, 317; **1932**, 392; **1933**, 315.
HBr (high)	Cubic	HCl (*h*)	5.76 at −170° C		**1931**, 316, 317; **1933**, 315.
HCl (low)	Orthorhombic	(*al*)	5.03	5.71 $b_0=5.35$	**1931**, 316, 317; **1933**, 315.
HCl (high)	Cubic	HCl (*h*)	5.46		**1931**, 316, 317; **1933**, 315.
HI	Tetragonal	(*am*)	6.19	6.68 at 125° K	**1931**, 316, 317; **1932**, 392.
HgF	Tetragonal	Hg_2Cl_2 (*g*)	3.66	10.9	**1933**, 122.
HgLi	Cubic	CsCl (*a*)	3.287		**1933**, 523.
KCN	Cubic	NaCl (*b*), (*an*)	6.51		**1931**, 319.
KHS (low)	Hexagonal	NaHS (*az*)	4.374	68°51′	**1934**, 287.
KHS (high, above ca 170° C)	Cubic	NaCl (*b*)	6.60		**1934**, 287.
LiGa	Cubic	NaTl (*ao*)	6.195		**1933**, 523.
LiH	Cubic	NaCl (*b*)			**1932**, 48.
LiIn	Cubic	NaTl (*ao*)	6.786		**1933**, 523.
LiOH	Tetragonal	PbO (*f*), (*ap*)	3.546	4.334	**1932**, 144; **1933**, 127.
LiTl	Cubic	CsCl (*a*)	3.424		**1933**, 523.
LiZn	Cubic	NaTl (*ao*)	6.209		**1933**, 523.
MgPr	Cubic	CsCl (*a*), (?)	3.88		**1933**, 387.
MgTl	Cubic	CsCl (*a*)	3.628		**1933**, 523.
MgZn	Hexagonal	(*aq*)	5.33	17.16	**1933**, 465.
MnO	Cubic	NaCl (*b*), (*ax*)			**1934**, 77.
MnS (red precipitate)	Cubic	ZnS (*c*)	5.600± 0.002		**1932**, 411; **1933**, 417.
MnS (green precipitate)	Cubic	NaCl (*b*), (*ax*)	5.212± 0.002		**1933**, 417; **1934**, 77.
MnS (red precipitate)	Hexagonal	ZnO (*d*)	3.976± 0.002	6.432± 0.004	**1932**, 411; **1933**, 417.
MoC	Hexagonal	(*ar*)	2.901	2.786	**1932**, 450.
γ-NH_4Br (at −100° C)	Tetragonal	(*ap*)	6.007	4.035	**1934**, 132.
NH_4HS	Tetragonal	PbO (*f*), (*ap*)	6.01	4.01	**1934**, 287.
NaBi	Tetragonal*		3.46	4.80	**1932**, 499.
NaCN	Cubic	NaCl (*b*)	5.83		**1931**, 319.
NaHS (low)	Hexagonal	NaHS (*az*)	3.986	68°5′	**1934**, 287.

* Said to contain one molecule and probably to be body-centered.

Substance	*Symmetry*	*Structure type*	a_0	c_0 or α	*References*
NaHS (high, above ca 90° C)	Cubic	NaCl (*b*)	6.05		**1934**, 287.
NaIn	Cubic	NaTl (*ao*)	7.297		**1933**, 526.
NaTl	Cubic	NaTl (*ao*)	7.473		**1932**, 500.
NiAs	Hexagonal*	NiAs (*e*)	3.602	5.009	**1933**, 130.
NiO	Cubic	NaCl (*b*)	4.1684± 0.0001		**1931**, 37, 272; **1933**, 87.
NiS	Hexagonal				**1931**, 264.
PbO (red)	Tetragonal	PbO (*f*)	3.968	5.011	**1932**, 120.
PbO (yellow)	Ortho-rhombic	(*x*)	5.459	5.859 b_0=4.723	**1932**, 120.
PtS (Cooperite)	Tetragonal	(*av*)	3.47	6.10	**1932**, 17.
(Pt, Pd, Ni)S (Braggite)	Tetragonal	(*as*)	6.37	6.58	**1932**, 17.
PtSn	Hexagonal	NiAs (*e*)	4.103	5.428	**1932**, 236; **1933**, 223.
RbCN	Cubic	NaCl (*b*)	6.82		**1931**, 319.
RbHS (low)	Hexagonal	NaHS (*az*)	4.525	69°20′	**1934**, 287.
RbHS (high)	Cubic	NaCl (*b*)	6.93 at ca 200° C		**1934**, 287.
SbZn	Ortho-rhombic	CdSb (*n*)	6.17	3.94 b_0=8.27	**1933**, 167.
SiC (II)	Hexagonal	(*y*), (*au*)	3.076	15.07	**1932**, 205; **1933**, 59.
SnAs	Cubic	NaCl (*b*), (*ay*)	5.681		**1934**, 295.
SnO	Tetragonal	PbO (*f*)			**1932**, 469.
SrNH	Cubic	NaCl (*b*)	5.45		**1934**, 103.
SrO	Cubic	NaCl (*b*)	5.144		**1933**, 80.
SrTl	Cubic	CsCl (*a*)	4.024		**1933**, 523.
TaC	Cubic	NaCl (*b*)	4.4460± 0.0005		**1933**, 424; **1934**, 42.
TiC	Cubic	NaCl (*b*)	4.320		**1931**, 59; **1932**, 414; **1934**, 42.
TlCN	Cubic	CsCl (*a*)	3.82		**1934**, 256a.
TlCl	Cubic	CsCl (*a*)	The value a_0=3.380 in **1933**, 302 is undoubtedly a misprint.		
VO	Cubic	NaCl (*b*)	4.08		**1932**, 302.
WC	Hexagonal		2.910	2.838	**1931**, 343.
ZnO	Hexagonal†	ZnO (*d*)	3.248	5.203	**1933**, 218.
ZrC	Cubic	NaCl (*b*)	4.687		**1934**, 42.

* There is no change in structure below 600° C.

† No change in structure between 110° and 1300° C.

$\frac{2}{3}\frac{1}{3}\frac{3}{4}$. The other atoms are similarly placed in both structures. The new copper parameter u=0.107 in (f) $\frac{1}{3}\frac{2}{3}$u; etc. is nearly the same as the old; the sulfur parameter v=0.062 in (e) 00v; etc. is considerably different. This new structure has the atomic separations characteristic of neutral atoms (Cu-S=2.20–2.35 A, S-S=2.05 A).

(*ai*) The values of a_0 for specimens of **FeO**, which invariably are deficient in iron, increase with the amount of iron present. For an oxide containing 76.08% Fe, $a_0 = 4.2816$ A; for a sample with 76.72% Fe, $a_0 = 4.3010$ A. By extrapolation pure FeO (77.73% Fe) would have $a_0 = 4.332$ A.

(*aj*) **Pyrrhotite** has the composition $Fe_1S_{(1+x)}$ not by reason of the presence of an excess of sulfur but because some of the iron atoms are missing from their structural positions. It is said that pure FeS gives evidence of a superlattice containing 12 molecules; the a_0 of this lattice is the diagonal of a_0 for the simple cell, its c_0 is twice as great: $a_0 = 5.946$ A, $c_0 = 11.720$ A.

Ordinary pyrrhotite ($a_0 = 3.41$ A, $c_0 = 5.72$ A) becomes ferromagnetic if heated above 200° C; this form, giving $a_0 = 3.47$ A, $c_0 = 5.84$ A at room temperature, reverts to the non-magnetic form if heated above 450° C (**1934**, 176).

(*ak*) From photographic data it has been concluded that the four molecules of **GeS** are in special positions (c) of the space group V_h^{16}:

$$\text{Ge: (c) } uv0;\ \bar{u}, \tfrac{1}{2}-v, \tfrac{1}{2};\ u+\tfrac{1}{2}, \bar{v}, \tfrac{1}{2};\ \tfrac{1}{2}-u, v+\tfrac{1}{2}, 0$$
$$\text{with } u=0.167,\ v=-0.125$$
$$\text{S: (c) } u'v'0;\ \text{etc. with } u'=v'=0.111.$$

The axes X′Y′Z′ of **1930**, 352 bear the following relation to the axes abc of this description: a=Z′, b=Y′, c=X′. The kind of packing that prevails is illustrated by Figure 276a and b.

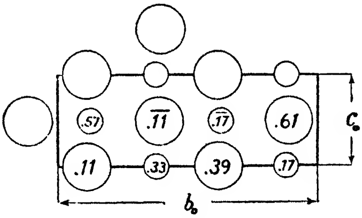


FIG. 276*a*.—The unit cell of the structure of GeS projected on an a-face. The large circles are sulfur.

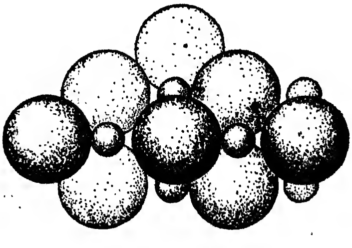


FIG. 276*b*.—A packing drawing of *a* with Ge and S atoms given their ionic sizes. In making these packing drawings it is sometimes better to show an atom at a height 1+x instead of the equivalent atom of height x. Thus in this figure the central sulfur atom is at 1−0.11=0.89 (and not at −0.11). Similarly its neighboring Ge is at 0.83 instead of −0.17, as in *a*.

(*al*) Earlier work described the low temperature modifications of **HCl** and **HBr** as tetragonal. The more recent experiments, however, make them orthorhombic pseudo-cubic with four molecules in the unit. The space group of low HBr is thought to be either V^7 or V_h^{23}.

(*am*) Cubic **HI** is not cubic, as first stated, but tetragonal. It is said that its transitions do not involve atomic rearrangements.

(*an*) A reexamination of **KCN** has failed to supply data indicating a unit larger than that of the four-molecule NaCl-like grouping.

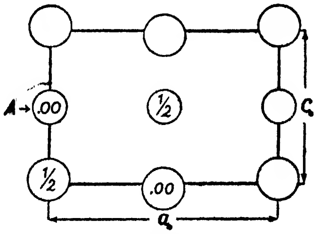
(*ao*) The **NaTl** superlattice, found for a number of alloys, contains eight molecules with atoms in the following special positions of O_h^7:

Tl: (8f) $000;\ \frac{1}{2}\frac{1}{2}0;\ \frac{1}{2}0\frac{1}{2};\ 0\frac{1}{2}\frac{1}{2};\ \frac{1}{4}\frac{1}{4}\frac{1}{4};\ \frac{1}{4}\frac{3}{4}\frac{3}{4};\ \frac{3}{4}\frac{1}{4}\frac{3}{4};\ \frac{3}{4}\frac{3}{4}\frac{1}{4}$
Na: (8g) $\frac{1}{2}\frac{1}{2}\frac{1}{2};\ 00\frac{1}{2};\ 0\frac{1}{2}0;\ \frac{1}{2}00;\ \frac{3}{4}\frac{3}{4}\frac{3}{4};\ \frac{3}{4}\frac{1}{4}\frac{1}{4};\ \frac{1}{4}\frac{3}{4}\frac{1}{4};\ \frac{1}{4}\frac{1}{4}\frac{3}{4}$.

(*ap*) Three additional crystals have been found to have the PbO (*f*) type of structure but with parameters and cells so different that other atomic relationships are produced.

Of these substances **LiOH** is most like PbO. Lithium atoms are in (a) $000;\ \frac{1}{2}\frac{1}{2}0$, OH groups are at (c) $0\frac{1}{2}u;\ \frac{1}{2}0\bar{u}$ with u said to be 0.20. If u is really so small there is a surprisingly large separation (ca 3.5 A) between the OH ions of adjacent layers.

The other two crystals with this grouping, **NH_4HS** and the γ-form of **NH_4Br**, photographed at −100° C, have identical units. Since in most compounds the HS ion has practically the same size as the bromide ion, it might be expected that the parameters defining them would be little different. In view of this fact it will be interesting to learn from future work whether the unlike parameters found for the bromide and hydrosulfide are both right. Expressing the atomic positions in the coordinates used for LiOH (above) and for PbO, u(HS) = 0.66 for NH_4HS; for γ-NH_4Br, u(Br) = 0.53. A drawing of the bromide is reproduced in Figure 277a and b for comparison with the PbO packing illustrated in Figure 176.



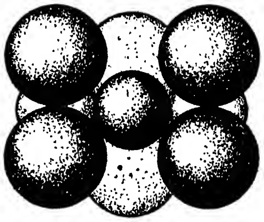


FIG. 277*a*.—(*left*) The variant of the tetragonal PbO (*f*) arrangement provided by the γ-form of NH_4Br. Small circles are NH_4 groups; the origin is in the NH_4 ion at A.

FIG. 277*b*.—(*right*) A packing drawing of γ-NH_4Br with the NH_4 group shown as the smaller sphere. It is evident that good packing results if, as in this drawing, the atoms are given their usual ionic sizes.

(*aq*) It is said that the structure of **MgZn** resembles that of $MgZn_2$ [see Chapter XII, (*ab*)] with two magnesium atoms in place of zinc atoms and with c_o doubled in length.

(*ar*) The molybdenum atom of the single **MoC** molecule in the unit is at the origin (000); the carbon atom is thought to be at $\frac{1}{3}\frac{2}{3}\frac{1}{2}$.

(*as*) The cell of **braggite** is reported to contain eight molecules and to have an arrangement based on D_{4h}^2. The sample that was studied contained 20% Pd and 5% Ni.

(*at*) The β-form of **CO**, stable above 61.5° K, has the same structure as β-nitrogen. If the arrangement found for β-N_2 is correct, this modification of CO, too, has rotating molecules in close-packed array.

(*au*) A Fourier analysis has been made of the basal reflections from an unspecified type of **SiC** (**1932**, 205).

(*av*) The tetragonal cell of the mineral **cooperite, PtS**, has been described as containing two molecules. Its atoms are thought to be in the following special positions of D_{4h}^9: Pt: (c) $0\frac{1}{2}0$; $\frac{1}{2}0\frac{1}{2}$, S: (e) $00\frac{1}{4}$; $00\frac{3}{4}$.

(*aw*) The unit cube of the modification of **AgI** stable above 146° C is supposed to contain two molecules. Iodine atoms are reported to be at 000; $\frac{1}{2}\frac{1}{2}\frac{1}{2}$; silver is described as occupying two of the 30 largest holes resulting from this iodine packing. Such an unusual structure needs further confirmation.

(*ax*) Measurements of a_o for cubic MnO at low temperatures show that there is no change in structure around 160° K where an anomalous heat change occurs. At this point there is, however, a minimum in the cubic edge length. Magnetite, Fe_3O_4, behaves similarly. MnS and FeO likewise do not have different crystal structures above and below the temperatures at which they show thermal anomalies. Neither do they have a region in which they contract on warming; instead they show two different rates of thermal expansion. The data for these conclusions are given in Table II.

TABLE II. VALUES OF a_o AT SEVERAL TEMPERATURES

Temperature	*a_o for Compound*			
	MnO	*Fe_3O_4*	*MnS*	*FeO*
299° K	4.436	8.363	5.210	4.290
200	—	—	—	4.286
186	—	—	—	4.284
160	4.409	8.357	5.204	4.283
143	—	—	5.204	—
138	—	—	5.197	—
130	—	—	5.192	—
114	4.416	8.363	—	—
104	4.419	8.363	—	—

(*ay*) The compound **SnAs** is especially interesting in being an example of the NaCl grouping which is capable of "dissolving" both components, the As-rich limit being at 49% As, the Sn limit at 34.5% As. The pure compound has the lowest value of a_0.

(*az*) The one-molecule rhombohedron of the form of the alkali hydrosulfides stable at room temperatures is very different in shape from that found for AgCN. Atomic parameters are not known for any of these crystals.

Chapter XIIA. Structures of the Type RX_2

(*as*) The monoclinic unit of **Ag_2Te** has been said to contain three molecules; this is improbable. A sample heated to 250° C and cooled in nitrogen showed no change in pattern.

(*at*) The diffraction lines of **BeF_2**, which were not very sharp, are reported to be those of a tetragonal high cristobalite-like (*ae, bd*) structure containing eight molecules.

(*au*) The atomic arrangement assigned to **COS** on the basis of low temperature powder photographs is developed from C_{3v}^5. The atoms in its single molecule rhombohedron are on three-fold axes with the coordinates uuu. For C, $u=0$; for S, $u'=0.33_6$; for O, $u_1=-0.18_7$. The resulting interatomic distances within the molecule are C-O=1.10 A, C-S=1.96 A; between different molecules O-S=2.78 A.

(*av*) The astonishingly large unit assigned to **Cu_2S** would contain 160 molecules.

(*aw*) **Marcasite (FeS_2)** and **löllingite ($FeAs^2$)** have been given smaller unit cells. These cells contain two molecules with atoms arranged according to V_h^{12}. Iron atoms are in (a) 000; $\frac{1}{2}\frac{1}{2}\frac{1}{2}$, sulfur (or arsenic) atoms in (g) $0uv$; $0\bar{u}\bar{v}$; $\frac{1}{2}, \frac{1}{2}-u, v+\frac{1}{2}$; $\frac{1}{2}, u+\frac{1}{2}, \frac{1}{2}-v$. The axes, abc, of this description and $X'Y'Z'$ of **1930**, 352 are connected by the relation $a=Z'$, $b=X'$, $c=Y'$. For FeS_2, $u=0.203$, $v=0.375$; for $FeAs_2$, $u'=0.175$, $v'=0.361$; for the more recently studied phosphide FeP_2, $u''=0.16$, $v''=0.37$. The grouping of marcasite, as typical of this structure, is illustrated in Figure 278a and b. It consists of open meshworks of iron atoms and

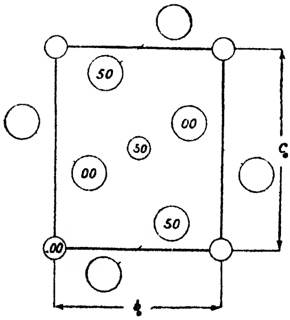


Fig. 278*a*.—(*left*) The new atomic arrangement deduced for marcasite, FeS_2, as projected upon the a-face of its orthorhombic cell. The small circles are Fe atoms.

Fig. 278*b*.—(*right*) A packing drawing of FeS_2 if Fe and S are shown with the radii of their neutral atoms. The line-shaded atoms are Fe.

TABLE I. THE CRYSTAL STRUCTURES OF THE COMPOUNDS RX_2

Substance, symmetry and structure type			a_0	c_0 *or* a	*References*
Ag_2S (Acanthite)	Ortho-rhombic	*(bf)*	4.77 $b_0=6.92$	6.88	**1931**, 124, 345.
Ag_2S (Argentite)	Cubic above 180° C	Cu_2O *(j)*, *(bf)*	4.90		**1931**, 124, 345.
Ag_2Te	Monoclinic	*(as)*	5.98 $b_0=6.31$, $\beta=75°2'$	5.56	**1932**, 444.
Al_2Au	Cubic	CaF_2 *(a)*	6.00		**1932**, 292.
AlCuMg	Hexagonal	$MgZn_2$ *(ab)*	5.09	8.35	**1934**, 339.
Au_2Pb	Cubic	$MgCu_2$ *(q)*	7.91		**1934**, 209a.
$AuSb_2$	Cubic	FeS_2 *(f)*	6.647		**1931**, 326; **1932**, 58; **1933**, 223.
BaF_2	Cubic	CaF_2 *(a)*	6.187		**1933**, 422.
Be_2C	Cubic	CaF_2 *(a)*	4.33		**1931**, 425; **1934**, 354b.
Be_2Cu	Cubic	$MgCu_2$ *(q)*	5.94		**1934**, 339.
BeF_2	Tetragonal	*(at)*	6.60	6.74	**1932**, 70.
Be_2Fe	Hexagonal	$MgZn_2$ *(ab)*	4.22	6.83	**1934**, 339.
CO_2	Cubic	CO_2 *(g)*, *(bg)*	5.575 at −190° C		**1931**, 458, 459; **1934**, 130, 130a.
COS	Hexagonal	*(au)*	4.08 at liquid air temp.	98°58′	**1931**, 457.
CaF_2	Cubic	CaF_2 *(a)*	5.451		**1933**, 422.
CaI_2	Hexagonal	CdI_2 *(c)*, *(bi)*	4.48	6.96	**1933**, 52.
$CdBr_2$	Hexagonal	*(bn)*			**1933**, 43.
CdCl(OH)	Hexagonal	*(bh)*	3.66	10.27	**1934**, 110.
CdI_2		*(c)*, *(bi)*			**1932**, 8; **1933**, 174.
$CoCl_2$	Hexagonal*	$CdCl_2$ *(e)*	6.16	33°26′	**1934**, 95.
CuF_2	Cubic	CaF_2 *(a)*	5.406		**1933**, 122.
Cu_2Mg	Cubic	*(q)*, *(bs)*			**1934**, 242.
Cu_2O	Cubic	Cu_2O *(j)*	4.252		**1931**, 321, 322; **1932**, 483.
Cu_2S	Ortho-rhombic	*(av)*	11.8 $b_0=27.2$	22.7	**1930**, 371.
$FeAs_2$	Ortho-rhombic	$FeAs_2$ *(i)*, *(aw)*	2.85 $b_0=5.25$	5.92	**1932**, 83.
Fe_2B	Tetragonal	*(t)*, *(bp)*			**1930**, 116a; **1931**, 146.
FeOCl	Ortho-rhombic	*(bj)*	3.75 $b_0=7.95$	3.3	**1934**, 84.
FeP_2	Ortho-rhombic	$FeAs_2$ *(aw)*	2.725 $b_0=4.975$	5.657	**1934**, 173.
FeS_2	Cubic	FeS_2 *(f)*, *(bk)*	5.405		**1932**, 352.
FeS_2	Ortho-rhombic	$FeAs_2$ *(i)*, *(aw)*	3.37 $b_0=4.44$	5.39	**1931**, 71.
GeO_2 ("Insoluble" form)	Tetragonal†	SnO_2 *(b)*	4.390	2.895	**1932**, 164.

* For $CoCl_2$, $u=0.25$.

† Parameter $u=0.3$.

Substance, symmetry and structure type			a_0	c_0 *or* α	*References*
H_2O	Hexagonal	(*x*), (*bl*)	4.508 at −66° C	7.338	**1933**, 257; **1934**, 16.
H_2S	Cubic	(*al*), (*ax*)			**1931**, 315, 456.
H_2Se	Cubic	(*al*), (*ax*)			**1931**, 315, 456.
$HgBr_2$	Orthorhombic	(*ay*)	6.85 $b_0=4.67$	12.45	**1931**, 461; **1932**, 66.
$HgCl_2$	Orthorhombic	(*y*), (*bm*)	5.963 $b_0=12.735$	4.324	**1932**, 332; **1934**, 316.
HgF_2	Cubic	CaF_2 (*a*)	5.54		**1933**, 122.
HgI_2	Orthorhombic	$HgBr_2$ (*ay*)	7.32 $b_0=4.674$	13.76	**1934**, 85.
KBi_2	Cubic	Cu_2Mg (*q*)	9.501		**1932**, 501.
K_2O	Cubic	CaF_2 (*a*)	6.436		**1934**, 309.
K_2S	Cubic	CaF_2 (*a*)	7.391		**1934**, 287, 309.
K_2Se	Cubic	CaF_2 (*a*)	7.676		**1934**, 309.
K_2Te	Cubic	CaF_2 (*a*)	8.152		**1934**, 309.
Li_2O	Cubic	CaF_2 (*a*)	4.619		**1934**, 309.
Li_2S	Cubic	CaF_2 (*a*)	5.708		**1934**, 309.
Li_2Se	Cubic	CaF_2 (*a*)	6.005		**1934**, 287, 309.
Li_2Te	Cubic	CaF_2 (*a*)	6.504		**1934**, 287, 309.
Mg_2Ge	Cubic	CaF_2 (*a*)	6.378		**1933**, 525.
MgI_2	Hexagonal	CdI_2 (*c*), (*bi*)	4.14	6.88	**1933**, 52.
$MgNi_2$	Hexagonal	$MgZn_2$ (*ab*)	4.81	7.95	**1934**, 339.
MgNiZn	Cubic	$MgCu_2$ (*q*)	6.96		**1934**, 339.
Mg_2Pb	Cubic	CaF_2 (*a*)	6.836		**1933**, 525.
Mg_2Sn	Cubic	CaF_2 (*a*)	6.765		**1933**, 525.
$MgZn_2$	Hexagonal	(*ab*)			**1934**, 260.
MnS_2 (Hauerite)	Cubic	FeS_2 (*f*)	6.097*		**1932**, 346, 411; **1933**, 417; **1934**, 204, 346.
Mo_2C	Hexagonal	(*az*)	2.994	4.722	**1932**, 450.
N_2O	Cubic	CO_2 (*g*)	5.656		**1931**, 458, 459.
NO_2	Cubic	(*an*), (*ba*)			**1931**, 170, 454, 455.
Na_2S	Cubic	CaF_2 (*a*)	6.526		**1934**, 309.
Na_2Se	Cubic	CaF_2 (*a*)	6.809		**1934**, 309.
Na_2Te	Cubic	CaF_2 (*a*)	7.314		**1934**, 309.
NdC_2	Tetragonal	CaC_2 (*k*)	3.81	6.36	**1931**, 425.
$NiBr_2$	Hexagonal	$CdCl_2$ (*e*), (*bn*)	6.46	33°20′	**1934**, 134.
NiI_2	Hexagonal	$CdCl_2$ (*e*)	6.92	32°40′	**1934**, 134.
$Ni(OH)_2$	Hexagonal	CdI_2 (*c*)	3.114	4.617	**1933**, 87.
OsS_2	Cubic	FeS_2 (*f*)	5.6075 ± 0.0006		**1934**, 174.
$PbBr_2$	Orthorhombic	$PbBr_2$ (*y*), (*bb*)			**1932**, 332.
PbFBr	Tetragonal	PbFBr (*bc*)	4.18	7.59	**1932**, 331.
$PbCl_2$	Orthorhombic	(*y*), (*bb*)	4.525 $b_0=7.608$	9.030	**1931**, 302; **1932**, 69.
PbFCl	Tetragonal	(*bc*)	4.09	7.21	**1932**, 330; **1933**, 323; **1934**, 9.

* u=0.4012.

Substance, symmetry and structure type			a_0	c_0 *or* a	*References*
α-PbF_2	Ortho-rhombic	(*y*), (*bb*)	3.80 $b_0=6.41$	7.61	1932, 269; 1933, 422.
β-PbF_2	Cubic*	CaF_2 (*a*)	5.942± 0.002		1933, 422.
PbO_2	Tetragonal	SnO_2 (*b*)	4.931	3.367	1932, 120.
PdF_2	Tetragonal	SnO_2 (*b*)	4.93	3.38	1931, 100.
PrC_2	Tetragonal	CaC_2 (*k*)	3.85	6.41	1931, 425.
$PtAs_2$ (Sperrylite)	Cubic	FeS_2 (*f*), (*br*)			1932, 17.
RuS_2 (Laurite)	Cubic	FeS_2 (*f*), (*br*)	5.59		1932, 17.
SaC_2	Tetragonal	CaC_2 (*k*)	3.75	6.28	1931, 425.
SiO_2 (α-Quartz, low)	Hexagonal	(*l*)	4.9029	5.3933	1930, 375; 1933, 62, 232, 277; 1934, 121a.
SiO_2 (α-Cristobalite, low)	Ortho-rhombic	(*bq*)	7.00 $b_0=7.00$	7.00	1932, 25.
SiO_2 (β-Cristobalite, high)	Cubic	(*ae*), (*bd*)			1932, 24.
SrC_2	Tetragonal	CaC_2 (*k*)	4.11†	6.68	1930, 299.
SrF_2	Cubic	CaF_2 (*a*)	5.784		1933, 422.
Ta_2C	Hexagonal	(*az*)	3.091	4.93	1934, 42.
YC_2	Hexagonal	(*bo*)	3.79	6.58	1931, 425.
$Zn(OH)_2$	Hexagonal (?)	CdI_2 (*c*), (*be*)	3.14	ca 5.12	1932, 146a.
$Zn(OH)_2$	Ortho-rhombic	(*ai*), (*be*)	8.53 $b_0=5.16$	4.92	1933, 104.
ZrW_2	Cubic	Cu_2Mg (*q*)	7.61		1933, 95.

* Transition between 220°–280° C.

† $a_0=5.81$ A as given in book, p. 239, applies to a larger diagonal cell.

sulfur pairs layered normal to the a-axes. The atomic contacts are perfect if iron and sulfur are given their radii as neutral atoms.

(*ax*) The patterns of H_2S and H_2Se indicate that the sulfur and selenium atoms are in face-centered array; nothing can of course be told about the hydrogen positions.

(*ay*) The four molecules in the unit of $HgBr_2$ are arranged according to the space group C_{2v}^{12}. All atoms are in special positions (a) $u0v$; $\bar{u}, 0, v+\frac{1}{2}$; $u+\frac{1}{2}, \frac{1}{2}, v$; $\frac{1}{2}-u, \frac{1}{2}, v+\frac{1}{2}$, with the parameters: for Hg, $u=0.33_4$, $v=0$; for Br′, $u'=0.05_6$, $v'=0.13_2$, for Br″, $u''=0.38_9$, $v''=0.36_8$. As Figure 279 shows, this arrangement is a typical layer-like structure, contact between the layers being maintained through bromine atoms. If the atoms are given their usual ionic sizes, as in the packing drawing, excellent contacts result.

Yellow mercuric iodide apparently has this $HgBr_2$ grouping.

(*az*) The two molybdenum atoms in the unit cell of $\mathbf{Mo_2C}$ are said to be at $\frac{1}{3}\frac{2}{3}\frac{1}{4}$; $\frac{2}{3}\frac{1}{3}\frac{3}{4}$; it is thought that the carbon atom may be at the origin 000. A tantalum carbide, Ta_2C, has the same hexagonal close-packing of its metal atoms; like W_2C it has a second modification.

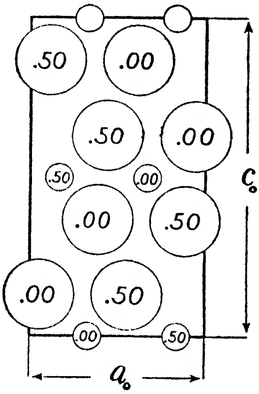
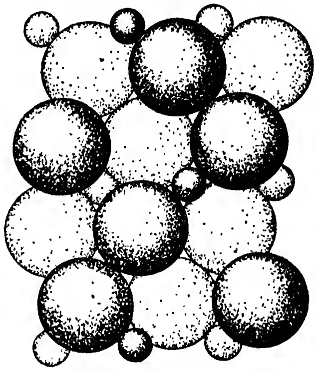


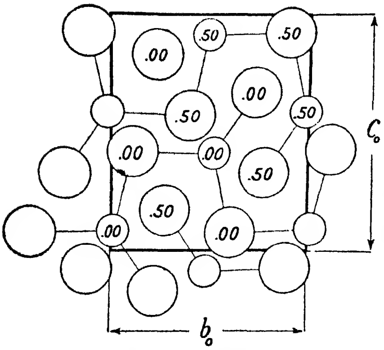
FIG. 279*a*.—(*left*) The layer structure of $HgBr_2$ projected on the b-face of its orthorhombic unit. The large circles are Br.

FIG. 279*b*.—(*right*) A packing drawing of $HgBr_2$ with the atoms having their ionic sizes.



(*ba*) The unit cube of solid $\mathbf{NO_2}$ contains 12 molecules. Two conflicting structure types have been proposed using the same data (**1931**, 454). In one of these, based on T^5, the nitrogen atoms are in (12c) $u0\frac{1}{4}$; etc. with $u=0.40_3$, the oxygen atoms in general positions xyz; etc. with $x=0.17_8$, $y=0.25$, $z=0.40_3$. This gives NO_2 molecules with an N-O separation of 1.38 A. The other discussion proceeds on the assumption that the solid ought to show N_2O_4 molecules. It is pointed out (**1931**, 170) that this can result if the space group is T^3 with oxygen atoms in general positions and nitrogen atoms in (12a) or (12b). The atomic positions have not been determined for such an arrangement but it is considered that the evidence favors planar molecules.

(*bb*) In the structures found for $\mathbf{PbBr_2}$ and $\mathbf{PbCl_2}$ all the atoms are in special positions (c) of V_h^{16}: $0uv$; $\frac{1}{2}, \frac{1}{2}-u, \bar{v}$; $0, u+\frac{1}{2}, \frac{1}{2}-v$; $\frac{1}{2}, \bar{u}, v+\frac{1}{2}$. In $PbBr_2$, $u(Pb)=0.01_5$, $v(Pb)=0.08_7$; for Br′, $u'=0.61$, $v'=0.07_5$, for Br″, $u''=0.23$, $v''=-0.17$. The different parameters given to the atoms in $PbCl_2$ are to be attributed to the choice of another origin. These parameters are: for Pb, $u=0.25_4$, $v=0.095$; for Cl′, $u'=0.65$, $v'=0.07$, for Cl″, $u''=0.55$, $v''=0.67$. The extreme layer-like nature of the structure possessed by both salts is illustrated by Figure 280; in b the atoms have been drawn with their customary ionic sizes. The packing is far less perfect than that found for $HgBr_2$ (Figure 279); but very possibly more accurate intensity data upon these lead salts would alter the chosen parameters enough to give them better ionic contacts.



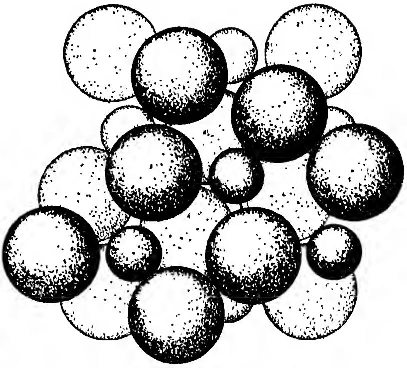


FIG. 280*a*.—(*left*) An a-face projection of the $PbBr_2$ arrangement. The small circles are the Pb atoms. All atoms are in layers normal to the a-axis.

FIG. 280*b*.—(*right*) A packing drawing of $PbBr_2$ with the atoms given their ionic sizes.

(*bc*) Photographic data have been used to show that the atoms in the two-molecule units of **PbFBr** and **PbFCl** are in the following special positions of D_{4h}^7:

$$\text{Pb: (c) } 0\tfrac{1}{2}u;\ \tfrac{1}{2}0\bar{u},\quad \text{Br(or Cl): (c) } 0\tfrac{1}{2}v;\ \tfrac{1}{2}0\bar{v},\quad \text{F: (a) } \tfrac{1}{2}\tfrac{1}{2}0;\ 000.$$

For PbFBr, $u=0.19_5$, $v=0.65$; for PbFCl, $u'=0.20$, $v'=0.65$ (Figure 281).

The mineral matlockite is not Pb_2Cl_2O but PbFCl with the structure described above.

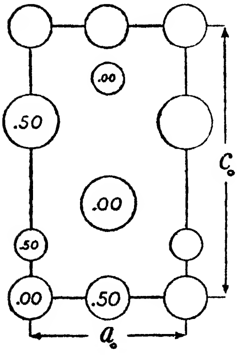
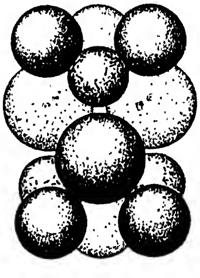


FIG. 281*a*.—(*left*) The unit cell of the PbFCl arrangement projected upon one of its tetragonal a-faces. The atom at the origin is F. The largest circles represent Cl atoms, the smallest Pb atoms.

FIG. 281*b*.—(*right*) A packing drawing of PbFCl if the atoms have their ionic sizes. The line-shaded spheres are Pb ions.



(*bd*) It is said that certain faint lines occur in the pattern of **high cristobalite, SiO_2**, which are not predicted by the holohedral structure (*ae*). A tetartohedral variant of this arrangement has accordingly been proposed in which the silicon atoms are in two sets of special positions (4f) of T^4: $uuu;\ u+\tfrac{1}{2}, \tfrac{1}{2}-u, \bar{u};\ \bar{u}, u+\tfrac{1}{2}, \tfrac{1}{2}-u;\ \tfrac{1}{2}-u, \bar{u}, u+\tfrac{1}{2}$ with $u=0.25_5$ and $u'=-0.00_8$.

The oxygen atoms are in another set of (4f) with $u''=0.12_5$ and in general positions xyz; etc. (see p. 267 of book) with $x=y=0.66$, $z=0.06$. The difference between this grouping and (*ae*) may be seen by comparing Figure 282 with Figure 194a. If the observed faint lines really are due to high cristobalite then this distortion of (*ae*), or a similar one, is necessary, but the proposed parameters do not provide better agreement with the strong lines than that given by (*ae*) itself. It is clear that more quantitative experimental data are required for an accurate placing of the atoms.

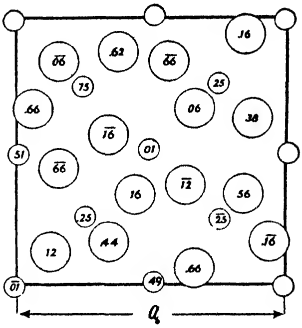


FIG 282.—The structure recently proposed for high (β) cristobalite (cf book, Figure 194*a*) The small circles are Si atoms

(*be*) The dimensions previously determined (**1927**, 104) do not refer to the orthorhombic form of **$Zn(OH)_2$** that has recently been analyzed using quantitative spectrometric data. The unit of the table, in which the a and b-axes of the original crystallographic description have been interchanged, contains four molecules. All its atoms are in general positions of V^4: xyz; $x+\frac{1}{2}, \frac{1}{2}-y, \bar{z}$; $\bar{x}, y+\frac{1}{2}, \frac{1}{2}-z$; $\frac{1}{2}-x, \bar{y}, z+\frac{1}{2}$, with the parameters of Table II. In this structure (Figure 283) each zinc atom is at the center

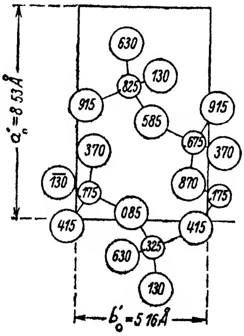


FIG 283*a*.—(*left*) The structure of orthorhombic $Zn(OH)_2$ projected upon its c-face The large circles are OH groups.

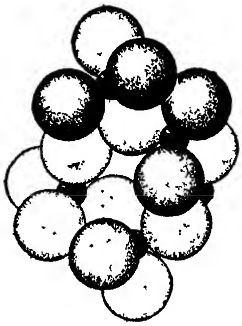


FIG 283*b*.—(*right*) The packing of the OH^- (large) and Zn^{++} ions in orthorhombic $Zn(OH)_2$.

TABLE II. PARAMETERS OF THE ATOMS IN $Zn(OH)_2$

Atom	*x*	*y*	*z*
Zn	0.125	0.100	0.175
O(1)	.025	.430	.085
O(2)	.325	.125	.370

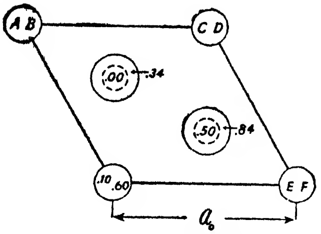
of a distorted tetrahedron of (OH) groups; each hydroxyl belongs to two such $Zn(OH)_4$ sphenoids. The result is a tetrahedral network somewhat resembling those found for the various forms of silica.

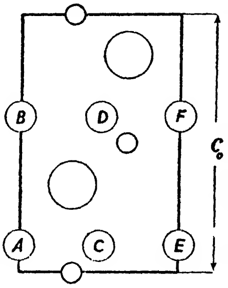
A hexagonal modification of $Zn(OH)_2$ has been said to exist with a CdI_2 (*c*) structure (**1932**, 146a). The available experimental evidence is not, however, satisfactory.

(*bf*) Above 180° C $\mathbf{Ag_2S}$ is cubic with the Cu_2O (*j*) structure; below this temperature the observed pattern is variously described as orthorhombic, like acanthite (**1931**, 124) and as a mixture of the acanthite and cubic patterns (**1931**, 345). Four molecules are contained in the acanthite unit described in Table I.

(*bg*) A reinvestigation of solid $\mathbf{CO_2}$ leads, as before, to the pyrite-like arrangement (*f*) with $u=0.11_6$. This gives a C-O distance of 1.13 A. Recent measurements of a_o between 20° and 114° K can be expressed by the equation $a_o=5.540+(4.679\times10^{-6})T^2$.

(*bh*) The two-molecule cell of **CdCl(OH)** has an atomic arrangement based on C_{6v}^4. Cadmium and chlorine are in special positions (b) $\frac{1}{3}\frac{2}{3}u$; $\frac{2}{3}, \frac{1}{3}, u+\frac{1}{2}$ with u (Cd)=0 and u′(Cl)=0.337. Hydroxyl groups are in (a) 00v; 0, 0, $v+\frac{1}{2}$ with v=0.100. This gives rise to the interionic contacts pictured in Figure 284a, b and c.





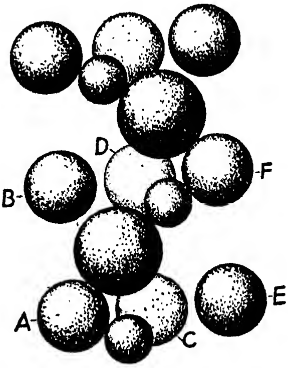


FIG. 284*a*.—(*left*) A basal projection of the Cd(OH)Cl arrangement. Cd, (OH) and Cl are represented by circles of increasing size. Letters refer to corresponding atoms in Figures 284*b* and 284*c*.

FIG. 284*b*.—(*center*) A diagonal (11·0) face projection of Cd(OH)Cl.

FIG. 284*c*.—(*right*) A packing drawing of *b* with the atoms of Cd(OH)Cl having their ionic sizes.

(*bi*) Lines have been found on powder and rotation photographs of $\mathbf{CdI_2}$ which indicate that the c-axis of the one-molecule cell should be doubled. It has been concluded that the atoms in this two-molecule cell are in the positions: Cd: 000; $\frac{1}{3}\frac{2}{3}\frac{1}{2}$, I: $\frac{1}{3}\frac{2}{3}u$; $\frac{2}{3}\frac{1}{3}\bar{u}$; 0, 0, $u+\frac{1}{2}$; $\frac{2}{3}, \frac{1}{3}, \frac{1}{2}-u$. It would seem to be proved that under certain circumstances CdI_2 can crystallize with this larger unit, but it is not clear whether it always has such a complicated structure and the existing data are insufficient to establish the new atomic arrangement. Additional work is especially needed since the original one-molecule structure (*c*) has been found to satisfy the diffraction data from a large number of different compounds. The additional lines calling for a larger unit have not been recorded from these other CdI_2-like crystals: some should show them clearly, others would not be expected to do so because of the relative scattering powers of their atoms.

(*bj*) It has been proposed that the atoms in the two-molecule unit of **FeOCl** are arranged according to the demands of the space group V_h^{13}. Oxygen and chlorine are placed in (a) $0u0$; $\frac{1}{2}\bar{u}\frac{1}{2}$ [interchange of Y and Z from **1930**, 352] and iron in (b) $0v\frac{1}{2}$; $\frac{1}{2}\bar{v}0$ with u (O) = −0.083, u(Cl) = 0.305, v = 0.097. So many crystals have in the past been incorrectly assigned to V_h^{13} that data far more complete and convincing than those yet published for FeOCl are highly desirable. It is also probable that the true atomic arrangement will be found to provide interatomic distances that differ somewhat from those of the structure outlined above.

(*bk*) A Fourier analysis has been made of quantitative intensity data from crystals of **pyrite** (**FeS_2**). This leads to a parameter u(S) = 0.386. The resulting atomic separations are S-S = 2.14 A, S-Fe = 2.26 A.

(*bl*) Within the limits of experimental error (ca ± 0.004) the dimensions of **ice** composed of heavy hydrogen are identical with those of ordinary ice. Structures have been proposed for ice which assign positions to its hydrogen atoms (see **1933**, 257); the results of X-ray determinations of course have nothing to say about such speculations.

(*bm*) From photographic data **$HgCl_2$** has recently been given a structure which is considered to be essentially molecular. Like $PbBr_2$ and $PbCl_2$ (*bb*), all atoms are in special positions (c) of V_h^{16}: $0uv$; $\frac{1}{2}$, $\frac{1}{2}-u$, $\bar{v}$; 0, $u+\frac{1}{2}$, $\frac{1}{2}-v$; $\frac{1}{2}$, $\bar{u}$, $v+\frac{1}{2}$. The parameters found for them are u(Hg) = 0.376, v = 0.053; u′(Cl′) = 0.517, v′ = 0.375; u″(Cl″) = 0.742, v″ = 0.778. The

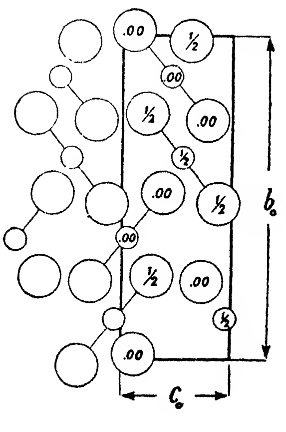
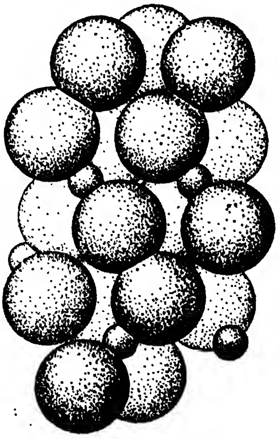


FIG. 284*d*.—(*left*) The structure found for $HgCl_2$ projected upon an a-face. Large circles are Cl atoms.

FIG. 284*e*.—(*right*) The type of packing that prevails in the $HgCl_2$ arrangement if atoms are given their ionic radii. In this drawing the atomic layer at ½ in *d* is on top.

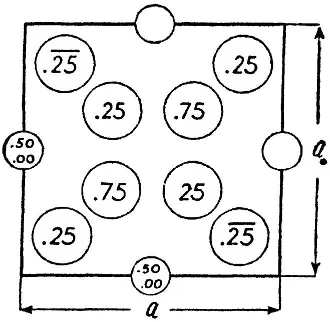


type of packing provided by this arrangement if the atoms have their usual ionic sizes is illustrated in Figure 284d and e. The nearest approach of Hg and Cl atoms is 2.25 A; Cl-Cl is 3.4 A.

(*bn*) $NiBr_2$ obtained by sublimation has the $CdCl_2$ arrangement (*e*) with u(Br)=0.255. The compound made by dehydration, by driving NH_3 from the hexammoniate or by recrystallization from alcohol is a "Wechselstruktur." The pattern for this gives $a_o = 2.11$ A, $c_o = 6.08$ A, a hexagonal cell which would contain only a third of a molecule. It has been proposed that these results can be interpreted in terms of an intimate twinning of $CdCl_2$ and CdI_2 structures—a few layers of each together. $CdBr_2$ has been found to give a similar "Wechselstruktur" with $a_o = 2.30$ A, $c_o = 6.23$ A; NiI_2 on the other hand seems always to have the $CdCl_2$ arrangement.

(*bo*) The structure of **YC_2** is different from that of the other carbides studied. It is supposed to be hexagonal with a two-molecule cell.

(*bp*) A new structure has been proposed for **Fe_2B** which differs from the previous one (*t*) in the parameters assigned to the Fe atoms at (i) of V_d^{11} and in the positions thought probable for the boron atoms. Borons are placed at (c) $\frac{1}{2}00$; $0\frac{1}{2}\frac{1}{2}$; $0\frac{1}{2}0$; $\frac{1}{2}0\frac{1}{2}$ instead of (a) and (b), and for Fe, $u = \frac{1}{6}$ and $v = \frac{1}{4}$ instead of $\frac{1}{5}$ (Figure 285). If $v = \frac{1}{4}$ is exactly correct the structure is identical with the one found for $CuAl_2$ (*n*), with a change of origin to $0\frac{1}{2}0$.



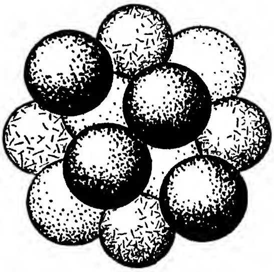


FIG. 285*a*.—(*left*) A basal projection of the new arrangement proposed for Fe_2B. The large circles are the Fe atoms.

FIG. 285*b*.—(*right*) A packing drawing of *a* if the Fe atoms are assumed to be neutral and if the (line-shaded) boron is given a size probable for its neutral atoms.

(*bq*) It is suggested that the unit cell of the room temperature (**low**) modification of **cristobalite** contains eight molecules and that the atomic arrangement, based on V^4, is a distortion of that of high cristobalite (compare Figure 286 with Figures 282 and 194a). All atoms are in general positions: xyz; $x+\frac{1}{2}, \frac{1}{2}-y, \bar{z}$; $\bar{x}, y+\frac{1}{2}, \frac{1}{2}-z$; $\frac{1}{2}-x, \bar{y}, z+\frac{1}{2}$. Parameters which are considered approximately correct are listed in Table III. As in the case of β-cristobalite, more quantitative data are needed to fix these atomic positions with any certainty.

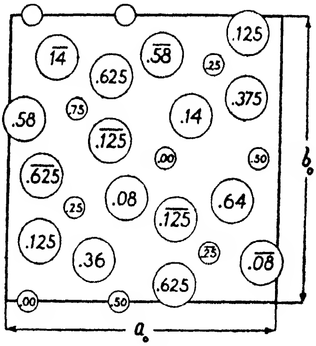


Fig. 286.—A c-face projection of the structure assigned to low temperature (α) cristobalite, SiO_2. The small circles are Si atoms.

TABLE III. PARAMETERS GIVEN TO THE ATOMS IN LOW CRISTOBALITE

Atom	*x*	*y*	*z*
O(1)	0.67	0.65	0.14
O(2)	.06	.64	.58
O(3)	.625	.06	.625
O(4)	.125	.21	.125
Si(1)	.25	.33	.25
Si(2)	.08	.00	.00

(*br*) The mineral **laurite** has been shown to be RuS_2 with the same pyrite structure (*f*) previously established for the synthetic compound. The sulfur parameter is $0.39 < u < 0.395$.

A further study of sperylite, also isomorphous with pyrite, has shown that $0.385 < u < 0.390$.

(*bs*) The compound **Cu_2Mg** has only a narrow range of homogeneity. On the α-side a_0 varies from 7.0087 A to 7.0185 A with annealing temperatures between 600° C and 400° C; two samples in the β+γ region annealed at 500° C and 380° C gave $a_0 = 7.0518$ A and $a_0 = 7.0343$ A.

Chapter XIIIA. Structures of the Type R_2X_3

(*m*) A complex arrangement which includes a place for one sodium atom per cell has been proposed for β-Al_2O_3. Based on D_{6h}^4 it has atoms in the following positions:

1 Na+1 Al: (a) $000;\ 00\tfrac{1}{2}$
4 Al: (f) $\tfrac{1}{3}\tfrac{2}{3}u;\ \tfrac{2}{3},\ \tfrac{1}{3},\ u+\tfrac{1}{2};\ \tfrac{2}{3}\tfrac{1}{3}\bar{u};\ \tfrac{1}{3},\ \tfrac{2}{3},\ \tfrac{1}{2}-u$ with $u=0.022$
3 Al: $\tfrac{3}{4}$ of positions of (f) with $u'=0.178$, 3 Al: same with $u''=-0.178$
12 Al: (k) $u\bar{u}v$; etc. (see **1930**, 352, p. 169) with $u=\tfrac{1}{6}$, $v=-0.106$
12 O: (k) $u_1\bar{u}_1v_1$; etc. with $u_1=\tfrac{1}{6}$, $v_1=0.05$
12 O: (k) $u_2\bar{u}_2v_2$; etc. with $u_2=\tfrac{1}{2}$, $v_2=0.144$
4 O: (f) $\tfrac{1}{3}\tfrac{2}{3}u_3$; etc. with $u_3=-0.05$
4 O: (e) $00w;\ 00\bar{w};\ 0,\ 0,\ \tfrac{1}{2}-w;\ 0,\ 0,\ w+\tfrac{1}{2}$ with $w=0.144$
$\tfrac{3}{2}$ O: $1\tfrac{1}{2}$ of two equivalent positions (c) $\tfrac{1}{3}\tfrac{2}{3}\tfrac{1}{4};\ \tfrac{2}{3}\tfrac{1}{3}\tfrac{3}{4}$,
$\tfrac{3}{2}$ O: same for (d) $\tfrac{1}{3}\tfrac{2}{3}\tfrac{3}{4};\ \tfrac{2}{3}\tfrac{1}{3}\tfrac{1}{4}$.

This distribution of atoms among the equivalent positions of the space group is so bizarre that a confirmation of the structure is much to be desired.

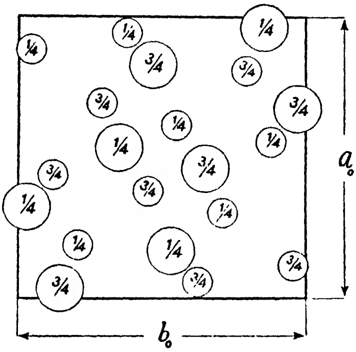
(*n*) The atomic arrangement in γ-Al_2O_3 has not yet been satisfactorily established.

TABLE I. PARAMETERS ASSIGNED TO THE ATOMS IN Sb_2S_3

Atom	*u*	*v*
Sb(1)	0.328	0.031
Sb(2)	–.039	–.149
S(1)	.883	.047
S(2)	–.439	–.125
S(3)	.194	.208

(*o*) Spectral photographs of **stibnite** indicate that the four Sb_2S_3 molecules in its orthorhombic unit are arranged according to V_h^{16}. All atoms are said to be in special positions (c) $uv\tfrac{1}{4};\ \bar{u}\bar{v}\tfrac{3}{4};\ \tfrac{1}{2}-u,\ v+\tfrac{1}{2},\ \tfrac{1}{4};\ u+\tfrac{1}{2},\ \tfrac{1}{2}-v,\ \tfrac{3}{4}$ with the parameters of Table I. If abc are the axes of this description and X′Y′Z′ are those of **1930**, 352: a=Z′, b=Y′, c=X′, the origin being moved to a center of symmetry. Within the limit of experimental error the Bi parameters in Bi_2S_3 are the same as those of Sb.

This structure consists of chains of the composition $(Sb_2S_3)_n$. If the atoms have their uncharged radii, there is good contact within these chains (Figure 287). Whether the atoms are charged or neutral the atoms in adjacent chains are unexpectedly far apart. In view of this fact it will be important to see whether future work confirms this arrangement.



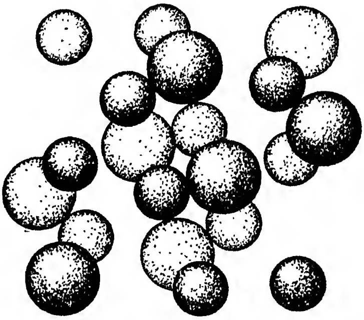


FIG. 287a.—(*left*) The arrangement proposed for stibnite, Sb_2S_3, projected on its c-face. The large circles are Sb atoms.

FIG. 287b.—(*right*) A packing drawing of *a* if Sb and S are given their neutral radii. The small spheres thus are the sulfur atoms. Packing is not improved by assuming that the atoms are charged.

(*p*) A reexamination of $\mathbf{Mg_3P_2}$ shows that its correct structure is identical with that of Tl_2O_3 (*b*). The selected parameters are the same as those found for bixbyite, $(Fe, Mn)_2O_3$. This atomic arrangement also prevails for Be_3P_2, Be_3N_2, Mg_3N_2 and α-Ca_3N_2.

It is said that Zn_3P_2, Cd_3P_2 and Zn_3As_2, though likewise possessed of 16-molecule cubic units, have different structures.

The earlier choice of a 12-molecule cube for Mg_3N_2 was due to a faulty estimate of its density.

Probably the small unit previously determined for Cd_3As_2 is equally wrong.

(*q*) The monoclinic unit assigned to $\mathbf{Cd_3Sb_2}$ contains four molecules.

(*r*) The structure first suggested for the magnetic γ-$\mathbf{Fe_2O_3}$ was the same as that of magnetite [(*k*) of Chapter XVI] with four oxygen atoms added. It has recently been shown that if these additional atoms are put in either of the two sets of positions originally proposed, the observed intensities cannot be explained. Better intensity agreement can be obtained by placing these atoms in (4g) uuu; etc. with $u=\frac{1}{8}$. The smallest O-O separations in this structure are greater than those existing in the previous arrangements; nevertheless they still have the improbably small value 2.14 A.

(*s*) Eight molecules of $\mathbf{Fe_3W_2}$ are contained in the large cell found for the ϵ-phase of the Fe-W system.

TABLE II. THE CRYSTAL STRUCTURES OF THE COMPOUNDS R_2X_3

Substance, symmetry and structure type			a_0	c_0 or α	*References*
Al_2Mg_3	Cubic	(*t*)	10.54		**1934**, 340.
α-Al_2O_3	Hexagonal	Fe_2O_3 (*a*)	5.13	55°6′	**1930**, 246b.
β-Al_2O_3	Hexagonal	(*f*), (*m*)	5.56	22.55	**1931**, 56.
γ-Al_2O_3	Cubic	(*n*)	7.90		**1932**, 18, 75.
As_2O_3	Cubic	As_2O_3 (*e*)	11.0457± 0.0002		**1932**, 290.
Be_3N_2	Cubic	Tl_2O_3 (*b*), (*p*)	8.134		**1933**, 443.
Be_3P_2	Cubic	Tl_2O_3 (*b*), (*p*)	10.15		**1933**, 443.
Bi_2S_3 (Bismuthinite)	Ortho-rhombic	Sb_2S_3 (*k*), (*o*)	11.13 $b_0=11.27$	3.97	**1933**, 207.
α-Ca_3N_2	Cubic	Tl_2O_3 (*b*), (*p*)	11.40		**1933**, 137, 443.
Cd_3As_2	Cubic	(*p*)	12.58 (?)		
Cd_3P_2	Cubic	(*p*)	12.26		**1933**, 443.
Cd_3Sb_2	Monoclinic	(*q*)	7.20 $b_0=13.51$, $\beta=100°14'$	6.16	**1933**, 167.
Cr_3C_2	Ortho-rhombic	(*g*)			**1931**, 468.
Cr_2O_3	Hexagonal	Fe_2O_3 (*a*)	5.38	54°50′	**1930**, 246b.
Fe_2O_3 (Hematite)	Hexagonal	Fe_2O_3 (*a*)	5.4135	55°17′	**1930**, 246b; **1932**, 75; **1933**, 247; **1934**, 34.
Fe_2O_3 (Magnetic)	Cubic	(*h*), (*r*)			**1931**, 117, 445.
Fe_3W_2 (ϵ-phase)	Hexagonal	(*s*)	4.738	25.726	**1931**, 343.
Mg_3As_2	Cubic	Tl_2O_3 (*b*), (*p*)	12.33		**1933**, 443, 524.
Mg_3Bi_2	Hexagonal	La_2O_3 (*c*)	4.666	7.401	**1933**, 524.
Mg_3N_2	Cubic	Tl_2O_3 (*b*), (*i*), (*p*)	9.95		**1932**, 185; **1933**, 443.
Mg_3P_2	Cubic	Tl_2O_3 (*b*), (*p*)	12.03		**1933**, 443, 524.
Mg_3Sb_2	Hexagonal*	La_2O_3 (*c*)	4.573	7.229	**1933**, 524.
Sb_2S_3 (Stibnite)	Ortho-rhombic	Sb_2S_3 (*k*), (*o*)	11.20 $b_0=11.28$	3.83	**1933**, 207.
Zn_3As_2	Cubic	(*p*)	11.74		**1933**, 443.
Zn_3P_2	Cubic	(*p*)	11.42		**1933**, 443.

* The parameters are the same as those of La_2O_3.

(*t*) The intermetallic phase Al_2Mg_3 gives the cubic pattern of α-Mn. It is therefore concluded that the true composition is $Mg_{17}Al_{12}$ with two molecules per cell. In such a structure Mg atoms presumably are in (2a), (8a) and (24g) (book, p. 270) with u=0.356, v=0.042; the Al atoms, also in (24g), have u′=0.089, v′=0.278.

Chapter XIVA. Structures of the Type RX_3, of Higher Compounds R_mX_n and of New Compounds of the Type $R_x(MX_2)_y$

The Compounds R_mX_n

(*al*) **AlF_3** was earlier described as hexagonal with a unit containing three molecules. An atomic arrangement more recently found for it is rhombohedral with two molecules in the unit (corresponding to a six-molecule hexagonal cell). The structure, based on D_3^7, has atoms in the special positions:

Al: (c) $uuu; \bar{u}\bar{u}\bar{u}$ with $u=0.237$
F: (d) $u_1\bar{u}_10; \bar{u}_10u_1; 0u_1\bar{u}_1$ with $u_1=0.430$
F: (e) $u'\bar{u}'\tfrac{1}{2}; \bar{u}'\tfrac{1}{2}u'; \tfrac{1}{2}u'\bar{u}'$ with $u'=0.070$.

(*am*) **Arsine, AsH_3,** and **phosphine, PH_3,** when solidified give patterns corresponding to four-molecule cubic cells. They are said to be face-centered but a further study of them is desirable to be sure that they do not have structures like ammonia (*t*).

(*an*) A previous determination has given **AsI_3**, SbI_3 and BiI_3 hexagonal unit cells containing six molecules. Atomic positions, said to be developed from C_3^1, were stated for BiI_3 [see (*b*)]. More recent work on AsI_3 has shown that its space group really is C_{3i}^2. The atoms in the two-molecule rhombohedron that is its true unit have the coordinates:

As: (c) $\pm(uuu)$ with $u=\tfrac{1}{6}$
I: (f) $\pm(xyz); \pm(zxy); \pm(yzx)$ with $x=0.42$, $y=0.08$, $z=0.75$.

If, as is presumably the case, SbI_3 and BiI_3 are isomorphous with AsI_3 then their two-molecule rhombohedral units will have the dimensions of Table I.

Though the space groups and the unit cell suggested for $CrBr_3$ are hexagonal, it is reported to be isomorphous with BiI_3. Its true unit is thus without doubt rhombohedral, the dimensions being those stated in Table I.

TABLE I. THE CRYSTAL STRUCTURES OF THE COMPOUNDS R_mX_n

Compounds RX_3

Substance, symmetry and structure type			a_0	c_0 or α	*References*
AlF_3	Hexagonal	(*i*), (*al*)	5.029	58°31′	1931, 256; 1933, 255.
Al_3Fe	Ortho-rhombic	(*bs*)	11.87 (?)	15.80 $b_0=8.09$	1933, 334; 1934, 313, 313a.
AsH_3	Cubic	(*am*)	6.40 at −170° C		1930, 429.
AsI_3	Hexagonal	AsI_3 (*b*), (*an*)	8.25	51°20′	1931, 205, 206.
BiI_3	Hexagonal	AsI_3 (*b*), (*an*)	8.13	54°50′	
$CaPb_3$	Cubic	$AuCu_3$ (*e*), (*ao*)	4.891		1933, 529.
$CaSn_3$	Cubic	$AuCu_3$ (*e*), (*ao*)	4.732		1933, 529.
$CaTl_3$	Cubic	$AuCu_3$ (*e*), (*ao*)	4.794		1933, 529.
(Ce, La, . . .)F_3 (Tysonite)	Hexagonal	(*ap*)			1931, 335.
$CeMg_3$	Cubic	$LaMg_3$ (*bc*)	7.373		1934, 234.
$CePb_3$	Cubic	$AuCu_3$ (*e*), (*ao*)	4.864		1933, 529.
$CeSn_3$	Cubic	$AuCu_3$ (*e*), (*ao*)	4.711		1933, 529.
CoF_3	Hexagonal	(*aq*)	3.66_4	87°20′	1931, 100.
$CrBr_3$	Hexagonal	AsI_3 (*b*), (*an*)	7.05	52°36′	1932, 68.
CrO_3	Ortho-rhombic (?)	(*as*)	8.50	5.72 $b_0=4.73$	1931, 53, 487.
Fe_3C	Ortho-rhombic	(*o*), (*av*)	4.626	6.633 $b_0=5.107$	1931, 343; 1932, 474.
$FeCl_3$	Hexagonal	AlF_3 (?) (*al*)	6.69	52°30′	1932, 481.
FeF_3	Hexagonal	(*aq*)	3.75_6	88°14′	1931, 100, 256; 1933, 511.
KCNS	Ortho-rhombic	(*aw*)	6.66	6.635 $b_0=7.58$	1933, 261; 1934, 38.
$LaMg_3$	Cubic	$LaMg_3$ (*bc*)	7.478		1934, 234.
$LaPb_3$	Cubic	$AuCu_3$ (*e*), (*ao*)	4.893		1933, 386.
$LaSn_3$	Cubic	$AuCu_3$ (*e*), (*ao*)	4.772		1933, 386.
$LiCd_3$		(*at*)			1933, 27; 1934, 310.
MoO_3	Ortho-rhombic	(*ax*)	3.954	3.694 $b_0=13.825$	1931, 53, 484, 485.
NH_3	Cubic	(*t*)	5.08 at −170° C		1930, 429.
NaCNO	Hexagonal	$CsCl_2I$ (*d*)	5.45	38°16′	1934, 287.
NaN_3	Hexagonal	$CsCl_2I$ (*d*), (*ar*)	5.45	38°48′	1934, 287.

Substance, symmetry and structure type			a_0	c_0 or α	*References*
$NaPb_3$	Cubic	$AuCu_3$ (*e*), (*ao*)	4.873		1931, 505.
PH_3	Cubic	(*am*)	6.31 at −170° C		1930, 429.
PI_3	Hexagonal	(*ay*)	7.11	7.42	1933, 64.
PdF_3	Hexagonal	(*aq*)	3.75_8	84°29′	1931, 100.
$PrMg_3$	Cubic	$LaMg_3$ (*bc*)	7.373		1934, 234.
RbN_3	Tetragonal	KN_3 (*c*)			1931, 72.
ReO_3	Cubic	(*az*)	3.734		1931, 44; 1932, 308; 1933, 45.
RhF_3	Hexagonal	(*aq*)	3.62	84°48′	1931, 100.
SbI_3	Hexagonal	AsI_3 (*b*), (*an*)	8.18	54°14′	
$SrPb_3$	Tetragonal	(*ba*)	4.955	5.025	1933, 529.
$TiAl_3$	Tetragonal	(*au*)	5.424	8.574	1931, 114.
TlCNS	Ortho-rhombic	(*aw*)	6.80	6.78 $b_0=7.52$	1934, 38, 256.
WO_3	Triclinic	(*bb*)	7.28	3.82 $b_0=7.48$*	1931, 53.

Compounds RX_4

CI_4	Cubic	(*bd*)	9.14		1931, 164.
Cr_4C	Cubic	(*x*)			1931, 468.
$Fe(CO)_4$	Monoclinic	(*be*)	13.00	11.41 $b_0=11.41$, $\beta=85°35'$	1931, 62.
HfF_4	Monoclinic	(*bt*)	9.45	7.62 $b_0=9.84$, $\beta=94°29'$	1934, 240a.
$LaAl_4$	Tetragonal	(*bf*)	13.2	10.2	1933, 385.
SiF_4	Cubic	(*bg*)			1930, 218a.
SiI_4	Cubic	SnI_4 (*aa*)	11.986		1931, 163.
$TiBr_4$	Cubic	SnI_4 (*aa*)	11.250		1932, 194.
TiI_4	Cubic	SnI_4 (*aa*)	12.002		1932, 194.
ZrF_4	Monoclinic	(*bt*)	9.46	7.64 $b_0=9.87$, $\beta=94°30'$	1934, 240a.

Compounds RX_5

$MgZn_5$	Hexagonal	(*bh*)	9.92	16.48	1933, 465.

Compounds RX_6

BaB_6	Cubic	ThB_6 (*ac*), (*bj*)	4.28		1931, 425; 1932, 6, 428.
B_6C (?)	Hexagonal	(*bu*)	5.62	12.12	1934, 338.
CaB_6	Cubic	ThB_6 (*bj*)	4.145		1931, 425; 1932, 6, 428; 1934, 207.
CeB_6	Cubic	ThB_6 (*bj*)	4.129		1931, 425; 1932, 6, 428.
ErB_6	Cubic	ThB_6 (*bj*)	4.102		1932, 6, 428.
GdB_6	Cubic	ThB_6 (*bj*)	4.12		1932, 6.
LaB_6	Cubic	ThB_6 (*bj*)	4.145		1931, 425; 1932, 6, 428.

---

* All angles close to 90°.

Substance, symmetry and structure type			a_0	c_0 or α	*References*
NdB_6	Cubic	ThB_6 (*bj*)	4.118		1932, 6, 428.
PrB_6	Cubic	ThB_6 (*bj*)	4.121		1932, 428.
SrB_6	Cubic	ThB_6 (*bj*)	4.19		1931, 425; 1932, 6, 428.
$Te(OH)_6$	Cubic	(*ab*), (*bi*)			1934, 88.
$Te(OH)_6$	Monoclinic	(*bi*)	5.54	9.74	1934, 88.
(second form)			$b_0=9.30$,	$\beta=104°30'$	
ThB_6	Cubic	ThB_6 (*bj*)	4.15		1932, 6.
YB_6	Cubic	ThB_6 (*bj*)	4.07		1932, 6.
YtB_6	Cubic	ThB_6 (*bj*)	4.13		1932, 6.

Higher Compounds RX_n

CsC_8	Hexagonal	KC_8 (*bk*)	4.94	23.76	1932, 405.
KC_8	Hexagonal	KC_8 (*bk*)	4.94	21.34	1932, 405.
RbC_8	Hexagonal	KC_8 (*bk*)	4.94	22.73	1932, 405.
CsC_{16}	Hexagonal	KC_{16} (*bl*)	4.94	18.51	1932, 405.
KC_{16}	Hexagonal	KC_{16} (*bl*)	4.94	17.45	1932, 405.
RbC_{16}	Hexagonal	KC_{16} (*bl*)	4.94	17.95	1932, 405.

Miscellaneous Compounds R_mX_n

Ag_3Hg_4	Cubic	(*bn*)	10.09		1933, 494.
Al_4C_3	Hexagonal	(*bv*)	8.53	22°28′	1934, 354c.
$B_{10}H_{14}$	Ortho-rhombic	(*bo*)	14.46 $b_0=20.85$	5.69	1931, 304.
Co_4S_3	Cubic		9.91		1932, 90.
Cr_7C_3	Hexagonal	(*af*)	13.98	4.52	1931, 468.
Cu_5Cd_8	Cubic	Cu_5Zn_8 (*ad*)			1931, 51.
$Cu_{15}Si_4$	Cubic	(*bq*)	9.694		1934, 179.
Cu_5Zn_8	Cubic	Cu_5Zn_8 (*ad*)			1931, 51.
$Na_{31}Pb_8$	Cubic	(*bp*)	13.27		1933, 451.
Sb_2Tl_7	Cubic	(*bm*)	11.59		1934, 180.
W_4O_{11}	Tetragonal	(*br*)	7.56	3.735	1934. 74.

TABLE II. NEW CRYSTAL STRUCTURES OF THE COMPOUNDS $R_x(MX_2)_y$

Substance, symmetry and structure type			a_0	c_0 or α	*References*
$AgClO_2$	Pseudo-tetragonal	(*ca*)	12.17	6.69	1931, 282.
$AgSbS_2$ (Miargyrite)	Monoclinic	(*cb*)	13.17 $b_0=4.39$,	12.82 $\beta=98°37\frac{1}{2}'$	1932, 219.
$(Ag, Cu)_2Sb_2S_4$ (Polybasite)	Ortho-rhombic (?)	(*cc*)	7.50 $b_0=12.99$	11.95	1934, 89.
CaB_2O_4	Ortho-rhombic	(*cd*)	6.19 $b_0=11.60$	4.28	1931, 494; 1932, 494.
$Ca(ClO_2)_2$	Pseudo-cubic	(*ce*)	5.80		1931, 282.
$CuBiS_2$ (Emplectite)	Ortho-rhombic	(*cf*)	6.12 $b_0=3.89$	14.51	1932, 219; 1933, 206.

Substance, symmetry and structure type			a_o	c_o or α	*References*
$Cu_2Fe_2O_4$	Hexagonal		6.06	2.82	**1934**, 281.
$CuFeS_2$ (Chalcopyrite)	Tetragonal	[XI, (*aa*)], (*cg*)	5.24	10.30	**1932**, 359.
$CuSbS_2$ (Wolfsbergite)	Ortho-rhombic	(*cf*)	6.01	14.46 b_o=3.78	**1932**, 219; **1933**, 206.
$KAg(CN)_2$	Hexagonal	(*ch*)	7.384	17.55	**1933**, 199.
$K_2Fe_2O_4$	Cubic	(*ci*)	7.958		**1933**, 197.
$KFeS_2$	Hexagonal	(*cj*)	13.03	5.40	**1933**, 329.
$Li_2Fe_2O_4$	Cubic	(*ck*)	4.141		**1931**, 362.
NH_4ClO_2	Tetragonal	(*cl*)	6.30	3.73	**1931**, 282.
NH_4HF_2	Ortho-rhombic	(*cm*)	8.33	3.68 b_o=8.14	**1932**, 196; **1933**, 349.
$NH_4H_2PO_2$	Ortho-rhombic	(*cr*)	3.98	11.47 b_o=7.57	**1934**, 307.
$Na_2Fe_2O_4$	Hexagonal	(*cn*)	5.59	35°20′	**1933**, 149.
$NaNO_2$	Ortho-rhombic	(*co*)	3.55	5.37 b_o=5.56	**1931**, 504.
$Pb(ClO_2)_2$	Pseudo-tetragonal	(*cp*)	4.14	6.25	**1931**, 282.
$PbFe_2O_4$	Cubic		7.81		**1933**, 197.
$TlAsS_2$ (Lorandite)	Monoclinic	(*cq*)	15.02	6.10 b_o=11.31, β=127°45′	**1932**, 219.

(*ao*) Several intermetallic compounds, of which **$NaPb_3$** is typical, have been found to have the simple cubic arrangement (*e*) which occurs as a superlattice in alloys of copper with gold, platinum and palladium. For $NaPb_3$ the atomic coordinates are: Na: (1a) 000, Pb: (3a) $0\frac{1}{2}\frac{1}{2}$; $\frac{1}{2}\frac{1}{2}0$; $\frac{1}{2}0\frac{1}{2}$ (Figure 288a and b).

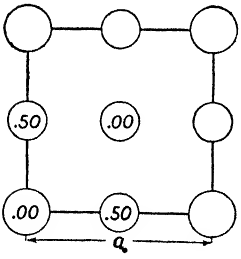
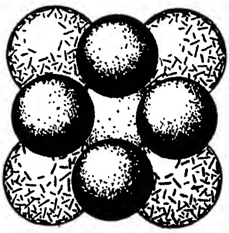


FIG. 288*a*.—(*left*) A cube face projection of the simple $NaPb_3$ grouping. Na atoms are at the origin.

FIG. 288*b*.—(*right*) A packing drawing of *a* with the atoms having the (neutral) radii found in the metals themselves. Na atoms are line-shaded.



(*ap*) A new structure has been suggested for **tysonite (Ce, La, . . .)F_3**= R′F_3. It has atoms of its six-molecule unit in the following special positions of D_{6h}^3:

R: (g) uu0; etc. (**1930**, 352, p. 168) with u=ca 0.34
F: (a) 000; $00\frac{1}{2}$, at (c) $\frac{1}{3}\frac{2}{3}0$; $\frac{2}{3}\frac{1}{3}\frac{1}{2}$; $\frac{2}{3}\frac{1}{3}0$; $\frac{1}{3}\frac{2}{3}\frac{1}{2}$ and at (k) u′u′v; etc.
with u′=ca $\frac{2}{3}$ and v=ca 0.175.

This arrangement is not definitely established by the existing data.

(*aq*) The data on **FeF_3** are conflicting. According to **1931**, 256 it is hexagonal with a three-molecule unit. The analysis of **1931**, 100 gives it a one-molecule rhombohedron having the dimensions recorded in Table I. A recent discussion suggests that neither of these is correct but that the arrangement really resembles that of WO_3 (*bb*). Whatever structure may ultimately be established for FeF_3, it probably is possessed by CoF_3, RhF_3 and PdF_3 as well. The one-molecule rhombohedral units, or pseudo-units, of these substances are listed in Table I.

(*ar*) The cell dimensions of **NaN_3** have been determined at 200° C as well as at room temperature. At the higher temperature the edge length is unchanged, $a_0 = 5.45$ A; the rhombohedral angle, however, has become slightly less acute, $\alpha = 39°14'$. The parameter u for nitrogen has not been established for any of the sodium compounds showing this arrangement; for $CsCl_2I$ it was 0.31.

(*as*) The unit cell of **CrO_3** contains four molecules. A structure based on V_h^{17} has been suggested but not proved.

(*at*) The data on **$LiCd_3$** are conflicting. According to one investigator it is cubic with a cell apparently holding 6 molecules; others state that the arrangement is hexagonal close-packed.

(*au*) The tetragonal unit of **$TiAl_3$** contains four molecules. An atomic arrangement has been described which, based on V_d^8, has atoms in the following special positions:

Ti: (a) $000; \frac{1}{2}0\frac{1}{2}; \frac{1}{2}\frac{1}{2}0; 0\frac{1}{2}\frac{1}{2}$ Al(1): (b) $\frac{1}{2}\frac{1}{2}\frac{1}{2}; 0\frac{1}{2}0; 00\frac{1}{2}; \frac{1}{2}00$
Al(2): (c) $\frac{1}{4}\frac{1}{4}\frac{1}{4}; \frac{3}{4}\frac{1}{4}\frac{3}{4}; \frac{3}{4}\frac{3}{4}\frac{1}{4}; \frac{1}{4}\frac{3}{4}\frac{3}{4}$ Al(3): (d) $\frac{3}{4}\frac{3}{4}\frac{3}{4}; \frac{1}{4}\frac{3}{4}\frac{1}{4}; \frac{1}{4}\frac{1}{4}\frac{3}{4}; \frac{3}{4}\frac{1}{4}\frac{1}{4}$.

(*av*) It has been found that the agreement between observed and calculated intensities from **Fe_3C** can be improved by altering very slightly the parameters of the iron atoms and by placing the carbon atoms in positions different from those previously suggested. As before, the iron atoms are in the following special positions of V_h^{16}:

Fe: (c) $uv\frac{1}{4}$; etc. (see p. 266 of book) with $u = 0.833$, $v = 0.04$
Fe: (d) xyz; etc. with $x = 0.333$, $y = 0.175$, $z = 0.065$.

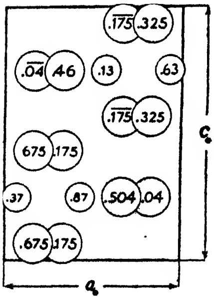
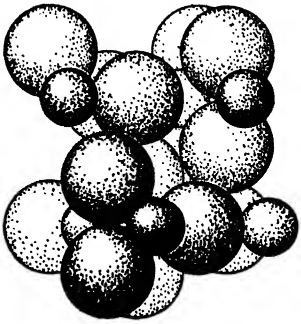


FIG. 289*a*.—(*left*) The improved structure for Fe_3C projected on the b-face of its orthorhombic cell. The large circles are the iron atoms.

FIG. 289*b*.—(*right*) A packing drawing of Fe_3C if the (larger) Fe atoms have their neutral (metallic) radii and the C atoms have the radius suggested by the diamond.



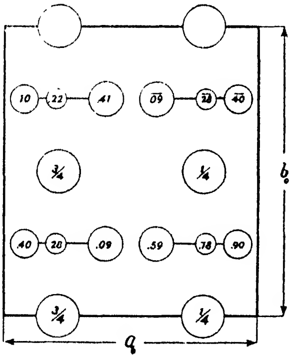
Instead of being in symmetry centers the carbon atoms are in another set of (c) $u'v'\frac{1}{4}$ with u′=0.43, v′=0.87. The resulting interatomic distances give iron the radius found in the metal, 1.25 A; the radius of carbon, 0.76 A, is that which occurs in the diamond (Figure 289a and b).

(*aw*) The orthorhombic unit of **KCNS** contains four molecules. A structure which gives fairly good agreement between calculated and photographically observed intensities is obtained by putting atoms in the following special positions of V_h^{11}:

$$\text{K: (c) } u'0\tfrac{3}{4};\ \bar{u}'\tfrac{1}{2}\tfrac{1}{4};\ \bar{u}'0\tfrac{1}{4};\ u'\tfrac{1}{2}\tfrac{3}{4} \text{ with } u'=0.212$$

$$\text{N, C, S: (d) } u\tfrac{1}{4}v;\ \bar{u}\tfrac{3}{4}\bar{v};\ \bar{u},\ \tfrac{1}{4},\ v+\tfrac{1}{2};\ u,\ \tfrac{3}{4},\ \tfrac{1}{2}-v \text{ with } u(S)=0.400,\ v(S)=0.095.$$

The suggested parameters for nitrogen are u(N)=0.080, v(N)=0.400; for carbon u(C)=0.205, v(C)=0.280. To derive the axes of this description (abc) from those of **1930**, 352 (X′Y′Z′) the transformations a=Z′, b=X′, c=Y′ are necessary. The kind of packing provided by this arrangement is illustrated by Figure 290.



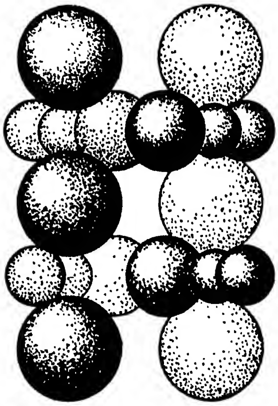


FIG. 290*a*.—(*left*) The structure assigned to KCNS as projected upon the c-face of its orthorhombic unit. The largest circles are K atoms; the others, in order of decreasing size, are S, N, and C.

FIG. 290*b*.—(*right*) A packing drawing of *a*. In this figure K atoms have their ionic size but for lack of better knowledge the other atoms have been assigned their neutral radii.

The thallium salt, TlCNS, probably has the same atomic grouping as KCNS. In fact one of the two studies (**1934**, 38) of TlCNS makes it orthorhombic with a similarly shaped unit and the same space group V_h^{11}. Another determination, which presumably is wrong, found it to be tetragonal with a unimolecular cell.

(*ax*) The orthorhombic unit of **MoO_3** contains four molecules. Two determinations agree in placing the molybdenum atoms in special positions (c) of V_h^{16}: $uv\frac{1}{4}$; etc. (see p. 266 of book). The parameters found for these atoms are practically identical: u=0.086 (0.088), v=0.099 (0.101). According to one study (**1931**, 484, 485) the oxygen atoms likewise are in three sets of these special positions (c) with $u_1=0.086$, $v_1=0.25$, $u_2=0.586$, $v_2=0.099$, $u_3=0.086$, $v_3=0.070$.

(*ay*) The unit cell of **PI_3** contains two molecules. It is said that the space group is C_6^6 with a structure similar to that of iodoform, CHI_3 [see p. 372 (*z*) of book]. The parameters chosen for the iodine atoms are x=0.30, y=0.35; z presumably being zero.

(*az*) No evidence has been obtained that the unit cube of **ReO_3** is larger than the one-molecule cell of the table. The Re atom is at the origin 000; it is thought that the three oxygen atoms are at (3b) $00\frac{1}{2}$; $0\frac{1}{2}0$; $\frac{1}{2}00$. This arrangement is said to resemble that of WO_3 which according to (*bb*) is triclinic.

(*ba*) The structure assigned to **$SrPb_3$** is a slight distortion of the $NaPb_3$ grouping (*ao*). The tetragonal unit contains one molecule with atoms in the following special positions: Sr: 000, Pb: $\frac{1}{2}\frac{1}{2}0$; $\frac{1}{2}0\frac{1}{2}$; $0\frac{1}{2}\frac{1}{2}$.

(*bb*) The cell of **WO_3** listed in the table contains four molecules. The following atomic arrangement, based on C_i^1, has been reported for its atoms:

W: (i) xyz; $\bar{x}\bar{y}\bar{z}$ with $x'=\frac{1}{4}$, $y'=\frac{1}{32}$, $z'=\frac{1}{16}$, and $x''=\frac{1}{4}$, $y''=\frac{17}{32}$, $z''=-\frac{1}{16}$
O: (a) 000, (d) $\frac{1}{2}00$, (c) $0\frac{1}{2}0$, (e) $\frac{1}{2}\frac{1}{2}0$,
(i) xyz; $\bar{x}\bar{y}\bar{z}$ with $x_1=\frac{1}{4}$, $y_1=\frac{9}{32}$, $z_1=0$; $x_2=\frac{1}{4}$, $y_2=-\frac{7}{32}$, $z_2=0$; $x_3=\frac{1}{4}$, $y_3=\frac{1}{32}$, $z_3=\frac{9}{16}$; $x_4=\frac{1}{4}$, $y_4=\frac{17}{32}$, $z_4=\frac{7}{16}$.

A more thorough study of WO_3 is obviously needed; whether this arrangement is correct or not, the unit described above is undoubtedly not the simplest one possible.

(*bc*) The cubic arrangement found for **$LaMg_3$** and several intermetallic compounds like it has four molecules in the special positions:

La: (4b) 000; $\frac{1}{2}\frac{1}{2}0$; $\frac{1}{2}0\frac{1}{2}$; $0\frac{1}{2}\frac{1}{2}$
Mg: (4c) $\frac{1}{2}\frac{1}{2}\frac{1}{2}$; $00\frac{1}{2}$; $0\frac{1}{2}0$; $\frac{1}{2}00$
Mg: (4d) $\frac{1}{4}\frac{1}{4}\frac{1}{4}$; $\frac{1}{4}\frac{3}{4}\frac{3}{4}$; $\frac{3}{4}\frac{1}{4}\frac{3}{4}$; $\frac{3}{4}\frac{3}{4}\frac{1}{4}$
Mg: (4e) $\frac{3}{4}\frac{3}{4}\frac{3}{4}$; $\frac{3}{4}\frac{1}{4}\frac{1}{4}$; $\frac{1}{4}\frac{3}{4}\frac{1}{4}$; $\frac{1}{4}\frac{1}{4}\frac{3}{4}$.

(*bd*) A new study of **CI_4** found diffraction lines incompatible with an SnI_4-like grouping. It is said that this new pattern corresponds to a four-molecule unit cube but no structure has been deduced.

(*be*) The large monoclinic cell of **$Fe(CO)_4$** described in the table is said to be built upon C_{2h}^6 and to contain 12 molecules. Making the doubtful assumption that this is the true unit it is concluded that the molecule of iron carbonyl is $[Fe(CO)_4]_3$.

(*bf*) The tetragonal cell of **$LaAl_4$** is thought to contain 16 molecules.

(*bg*) An analysis which is undoubtedly wrong makes **SiF_4**, solidified at −170° C, cubic with a two-molecule unit having $a_o = 5.41$ A. Faulty interatomic distances prevail in the suggested arrangement.

(*bh*) The unit chosen for **$MgZn_5$** is said to contain 16 molecules. A structure derived from that given to MgZn has been discussed.

(*bi*) A recent study of **telluric acid, $Te(OH)_6$**, contains evidence which is thought to show that the unit of its cubic modification is not the large 32-molecule cell previously found. This new cube contains four molecules and has half the edge length, $a_o = 7.83$ A.

Four molecules are also to be found in the monoclinic unit of the second form of $Te(OH)_6$; the space group is reported to be C_{2h}^5.

(*bj*) The unit cube of the **ThB_6** arrangement contains a single molecule and is based on O_h^1. Placing the metal atom at the origin 000, the boron atoms form an octahedron with the coordinates (Figure 291a):

$$B: (6d)\ \tfrac{1}{2}\tfrac{1}{2}u;\ \tfrac{1}{2}u\tfrac{1}{2};\ u\tfrac{1}{2}\tfrac{1}{2};\ \tfrac{1}{2}\tfrac{1}{2}\bar{u};\ \tfrac{1}{2}\bar{u}\tfrac{1}{2};\ \bar{u}\tfrac{1}{2}\tfrac{1}{2}.$$

In CaB_6, which has been studied more fully than the other compounds of this type, $u = 0.207$ giving a B-B separation of 1.716 A. In Figure 291b where the origin has been translated to a B_6 center at $\tfrac{1}{2}\tfrac{1}{2}\tfrac{1}{2}$, the structure appears as a body-centered CsCl packing of metal atoms and boron octahedra.

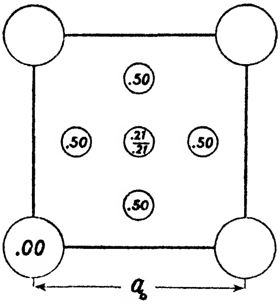


FIG. 291*a*.—(*left*) The unit of the CaB_6 grouping projected on a cube face. Small circles are B atoms.

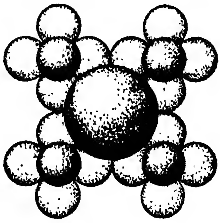


FIG. 291*b*.—(*right*) A packing drawing of CaB_6 giving the atoms their neutral radii. The calcium atom at the origin of *a* has been translated to the cube center of this drawing.

(*bk*) The **brown alkali graphites** have been given the composition RC_8. Their four-molecule hexagonal cells have $a_o = 4.94$ A, twice that of graphite. The alkali atoms are between the graphite layers in positions which have not been exactly fixed.

(*bl*) The **black alkali graphites** are said to be RC_{16}. Their units containing two molecules also have bases with twice the edge length and four times the area of graphite. It is considered that they are derived from the brown graphites by allowing alternate layers of alkali atoms to distill away.

(*bm*) Crystals of the intermetallic compound **Sb_2Tl_7** provide an example of a body-centered cubic superlattice. Atomic positions in the four-molecule cube, as determined from photographic data, are the following special positions of O_h^9 (**1930**, 352, p. 148):

12 Sb: (12a) $\pm(u00);\ \pm(0u0);\ \pm(00u)$ and 6 similar points about $\frac{1}{2}\frac{1}{2}\frac{1}{2}$, with $u=0.29$
2 Tl: (2a) $000;\ \frac{1}{2}\frac{1}{2}\frac{1}{2}$
16 Tl: (16d) $\pm(u'u'u');\pm(u'\bar{u}'\bar{u}');\pm(\bar{u}'u'\bar{u}');\pm(\bar{u}'\bar{u}'u')$ and 8 similar points about $\frac{1}{2}\frac{1}{2}\frac{1}{2}$ with $u'=0.16_7$
24 Tl: (24j) $\pm(u_1u_10);\pm(u_1\bar{u}_10);\pm(0u_1u_1);\pm(0u_1\bar{u}_1);\pm(u_10u_1);\pm(\bar{u}_10u_1)$ and 12 similar points about $\frac{1}{2}\frac{1}{2}\frac{1}{2}$ with $u_1=0.35$.

(*bn*) The atomic arrangement given to **Ag_3Hg_4** has a four-molecule unit cube with atoms in the following special positions of O_h^9:

Ag: (12h) $\frac{1}{2}0\frac{1}{4};\ \frac{1}{2}0\frac{3}{4};\ \frac{1}{4}\frac{1}{2}0;\ \frac{3}{4}\frac{1}{2}0;\ 0\frac{1}{4}\frac{1}{2};\ 0\frac{3}{4}\frac{1}{2}$ and 6 similar coordinates about $\frac{1}{2}\frac{1}{2}\frac{1}{2}$
Hg: (16d) $uuu;\ u\bar{u}\bar{u};\ \bar{u}u\bar{u};\ \bar{u}\bar{u}u;\ \bar{u}\bar{u}\bar{u};\ \bar{u}uu;\ u\bar{u}u;\ uu\bar{u}$ and 8 similar coordinates about $\frac{1}{2}\frac{1}{2}\frac{1}{2}$ with $u=0.192$.

(*bo*) The orthorhombic unit assigned to **$B_{10}H_{14}$** would contain eight molecules; its space group is said to be V_h^{21}.

(*bp*) The so-called **Na_4Pb** phase of the Na-Pb system has been said to be actually $Na_{31}Pb_8$ with a cubic structure like that of $Cu_{31}Sn_8$ (*ad*).

(*bq*) The complete structure found for the cubic intermetallic compound **$Cu_{15}Si_4$** is developed from T_d^6. Silicon atoms in its four-molecule cell are in (**1930**, 352, p. 131):

(16f) $uuu;\ u,\ \bar{u},\ \frac{1}{2}-u;\ \frac{1}{2}-u,\ u,\ \bar{u};\ \bar{u},\ \frac{1}{2}-u,\ u;\ u+\frac{1}{4},\ u+\frac{1}{4},\ u+\frac{1}{4};$
$\frac{1}{4}-u,\ u+\frac{1}{4},\ \frac{3}{4}-u;\ u+\frac{1}{4},\ \frac{3}{4}-u,\ \frac{1}{4}-u;\ \frac{3}{4}-u,\ \frac{1}{4}-u,\ u+\frac{1}{4}$

and similar points about $\frac{1}{2}\frac{1}{2}\frac{1}{2}$, with $u=0.208$. Copper atoms are in:

(12k) $\frac{3}{8}0\frac{1}{4};\ \frac{1}{8}0\frac{3}{4};\ \frac{1}{4}\frac{3}{8}0;\ \frac{3}{4}\frac{1}{8}0;\ 0\frac{1}{4}\frac{3}{8};\ 0\frac{3}{4}\frac{1}{8}$ and similar points about $\frac{1}{2}\frac{1}{2}\frac{1}{2}$

and in

(e) $xyz;\ x,\ \bar{y},\ \frac{1}{2}-z;\ \frac{1}{2}-x,\ y,\ \bar{z};\ \bar{x},\ \frac{1}{2}-y,\ z;$
$zxy;\ \frac{1}{2}-z,\ x,\ \bar{y};\ \bar{z},\ \frac{1}{2}-x,\ y;\ z,\ \bar{x},\ \frac{1}{2}-y;$
$yzx;\ \bar{y},\ \frac{1}{2}-z,\ x;\ y,\ \bar{z},\ \frac{1}{2}-x;\ \frac{1}{2}-y,\ z,\ \bar{x};$
$y+\frac{1}{4},\ x+\frac{1}{4},\ z+\frac{1}{4};\ \frac{1}{4}-y,\ x+\frac{1}{4},\ \frac{3}{4}-z;\ y+\frac{1}{4},\ \frac{3}{4}-x,\ \frac{1}{4}-z;\ \frac{3}{4}-y,\ \frac{1}{4}-x,\ z+\frac{1}{4};$
$x+\frac{1}{4},\ z+\frac{1}{4},\ y+\frac{1}{4};\ x+\frac{1}{4},\ \frac{3}{4}-z,\ \frac{1}{4}-y;\ \frac{3}{4}-x,\ \frac{1}{4}-z,\ y+\frac{1}{4};\ \frac{1}{4}-x,\ z+\frac{1}{4},\ \frac{3}{4}-y;$
$z+\frac{1}{4},\ y+\frac{1}{4},\ x+\frac{1}{4};\ \frac{3}{4}-z,\ \frac{1}{4}-y,\ x+\frac{1}{4};\ \frac{1}{4}-z,\ y+\frac{1}{4},\ \frac{3}{4}-x;\ z+\frac{1}{4},\ \frac{3}{4}-y,\ \frac{1}{4}-x$

and similar points about $\frac{1}{2}\frac{1}{2}\frac{1}{2}$ with $x=0.12,\ y=0.16,\ z=-0.04$.

(*br*) A tetragonal tungsten oxide, of the apparent composition **W_4O_{11}**, has been found to have a unit of almost the same size and shape as the triclinic unit assigned to WO_3. One W_4O_{11} molecule is contained in this cell and it is thought that its atomic arrangement is practically the same as that of WO_3 with one oxygen atom per cell removed.

(*bs*) The unit prism of **Al_3Fe** (Table I) is said to contain 24 molecules. A recent study makes a_o four times as big (47.43 A) with V_h^{23} as space group. Such a cell is reported to have in it 400 atoms.

(*bt*) The large cells of **HfF_4** and **ZrF_4** of Table I would enclose 12 molecules. The space group is C_{2h}^6.

(*bu*) If boron carbide is **B_6C**, calculation would give it 2.19 molecules per cell. Its composition is therefore considered to be in doubt. The space group is D_{3d}^5.

(*bv*) A rhombohedral unit containing one molecule has been found for **aluminum carbide, Al_4C_3**. It is said that the Al atoms are in two sets of special positions: (c) ±(uuu) of D_{3d}^5 with $u_1=0.293$ and $u_2=0.128$. Two of the three C atoms are in another set with $u'=0.217$; the third is at the origin (a) 000.

New Structures of the Type $R_x(MX_2)_y$

(*ca*) The pseudo-tetragonal unit assigned to **$AgClO_2$** is supposed to include 16 molecules.

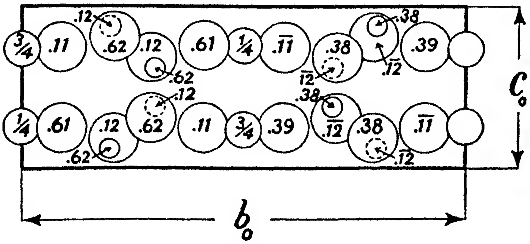
(*cb*) The cell described for the monoclinic sulfide **miargyrite, $AgSbS_2$**, contains eight molecules. The space group is reported to be C_{2h}^6.

(*cc*) The possibly orthorhombic mineral **polybasite $(Ag, Cu)_2Sb_2S_4$**, has been given an eight-molecule cell. A space group assignment is V_h^{19}.

(*cd*) The orthorhombic unit of **CaB_2O_4** contains four molecules. An atomic arrangement found from photographic data places atoms in the following positions of V_h^{14}:

Ca: (c) $\frac{1}{4}0u$; $\frac{3}{4}0\bar{u}$; $\frac{1}{4}, \frac{1}{2}, u+\frac{1}{2}$; $\frac{3}{4}, \frac{1}{2}, \frac{1}{2}-u$ with $u=0.26$
B: (d) xyz; $x+\frac{1}{2}, \frac{1}{2}-y, \frac{1}{2}-z$; $\bar{x}, y+\frac{1}{2}, \frac{1}{2}-z$; $\frac{1}{2}-x, \bar{y}, z$; $\bar{x}\bar{y}\bar{z}$; $\frac{1}{2}-x, y+\frac{1}{2}, z+\frac{1}{2}$;
$x, \frac{1}{2}-y, z+\frac{1}{2}$; $x+\frac{1}{2}, y, \bar{z}$ with $x=0.12$, $y=0.20$, $z=0.88$
O_1: (d) $x_1y_1z_1$; etc. with $x_1=0.125$, $y_1=0.21$, $z_1=0.19$
O': (d) $x'y'z'$; etc. with $x'=0.11$, $y'=0.09$, $z'=0.75$.

The axes of this description are the same as those of **1930**, 352; the origin is in a symmetry center at $\frac{1}{4}0\frac{1}{4}$. The linked B-O tetrahedra which make up the framework of this crystal can be seen from Figure 292a and b.



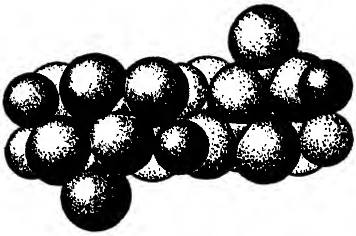


FIG. 292*a*.—(*left*) Atoms in the unit prism of CaB_2O_4 projected on the a-face. The largest circles are O atoms; intermediate ones are Ca.

FIG. 292*b*.—(*right*) A packing drawing of *a* with Ca and O atoms having their ionic radii. The way the BO_4 tetrahedra are linked together by sharing oxygen atoms is clearly seen.

(*ce*) The pseudo-cube ascribed to $\mathrm{Ca(ClO_2)_2}$ is bimolecular.

(*cf*) The orthorhombic unit of **emplectite, $\mathrm{CuBiS_2}$**, contains four molecules; its space group is V_h^{16}. The corresponding antimony compound wolfsbergite, $\mathrm{CuSbS_2}$, is structurally isomorphous.

(*cg*) A redetermination of the structure of **chalcopyrite, $\mathrm{CuFeS_2}$**, has led to a somewhat more complicated arrangement. The unit prism, with the same base, has twice the previous height and contains four molecules. Atoms, in special positions of V_d^{12}, are at:

Cu: (a) $000;\ \tfrac12 0\tfrac14;\ \tfrac12\tfrac12\tfrac12;\ 0\tfrac12\tfrac34$, Fe: (b) $00\tfrac12;\ \tfrac12 0\tfrac34;\ \tfrac12\tfrac12 0;\ 0\tfrac12\tfrac14$

S: (d) $\tfrac14 u\tfrac18;\ u\tfrac34\tfrac78;\ \tfrac34\bar{u}\tfrac18;\ \bar{u}\tfrac14\tfrac78;\ \tfrac34,\ u+\tfrac12,\ \tfrac58;\ u+\tfrac12,\ \tfrac14,\ \tfrac38;\ \tfrac14,\ \tfrac12-u,\ \tfrac58;\ \tfrac12-u,\ \tfrac34,\ \tfrac38$

with $u=0.27$. The resulting atomic separations, Cu-S = 2.32 A, Fe-S = 2.20 A, are those to be expected from neutral atoms (Figure 293a and b).

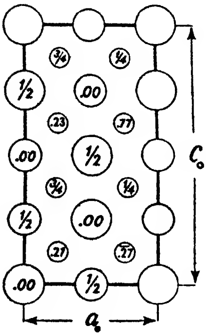
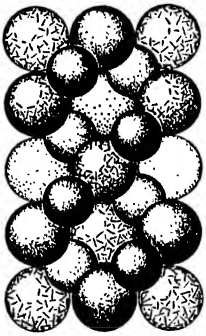
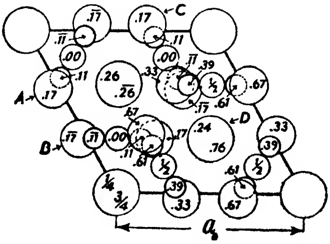


FIG. 293*a*.—(*left*) The new arrangement found for chalcopyrite, $\mathrm{CuFeS_2}$, as projected upon an a-face. Cu atoms are at the origin; intermediate circles are the Fe and the smallest circles the S atoms.

FIG. 293*b*.—(*right*) A packing drawing of $\mathrm{CuFeS_2}$ giving the atoms their neutral radii. The line-shaded spheres are Cu.





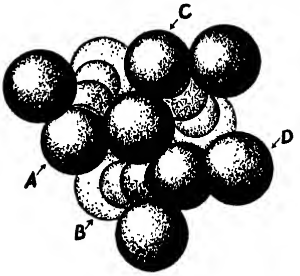


FIG. 294*a*.—(*left*) A basal projection of the atoms in the hexagonal unit of the structure found for $\mathrm{KAg(CN)_2}$. The largest circles are K atoms, the small heavy ones are C; of the intermediate circles the smaller represent the Ag atoms.

FIG. 294*b*.—(*right*) A packing drawing showing half the contents of the unit prism of $\mathrm{KAg(CN)_2}$. Corresponding atoms in *a* and *b* are designated by the same letters. Potassium and silver (line-shaded) atoms have their ionic radii but the sizes of C and N are probably without real significance.

(*ch*) The six-molecule unit found for **$\mathrm{KAg(CN)_2}$** has an arrangement based on D_{3d}^2. Its atomic positions have been given as (Figure 294):

K: (b) $00\frac{1}{4}; 00\frac{3}{4}$ K′: (f) $\frac{1}{3}\frac{2}{3}u; \frac{1}{3}\frac{2}{3}\bar{u}; \frac{2}{3}, \frac{1}{3}, \frac{1}{2}-u; \frac{2}{3}, \frac{1}{3}, u+\frac{1}{2}$ with $u=0.260$
Ag: (h) $u\bar{u}0; 2\bar{u}, \bar{u}, 0; u, 2u, 0; \bar{u}u\frac{1}{2}; 2u, u, \frac{1}{2}; \bar{u}, 2\bar{u}, \frac{1}{2}$ with $u=0.167$
C: (i) $xyz; y-x, \bar{x}, z; \bar{y}, x-y, z; x, x-y, \bar{z}; \bar{y}\bar{x}\bar{z}; y-x, y, \bar{z}; \bar{x}, \bar{y}, \frac{1}{2}-z;$
$x-y, x, \frac{1}{2}-z; y, y-x, \frac{1}{2}-z; \bar{x}, y-x, z+\frac{1}{2}; y, x, z+\frac{1}{2}; x-y, \bar{y}, z+\frac{1}{2}$

with $x=0.295$, $y=\frac{1}{3}$, $z=0.109$

N: (i) $x'y'z'$; etc. with $x'=0.365$, $y'=\frac{1}{3}$, $z'=0.167$.

In all other cyanides it has not been possible to establish the separate positions of carbon and nitrogen. Instead the cyanide radical seems to have the spatial characteristics of a sphere with a radius substantially that of the bromide ion. For this reason it is not clear how much significance is to be attached to the C and N parameters stated above and to the short K-N separation (2.56 A) that results.

(*ci*) The unit cube assigned to $\mathbf{K_2Fe_2O_4}$ is reported to contain four molecules.

(*cj*) Eight molecules are associated with the hexagonal prism of $\mathbf{KFeS_2}$.

(*ck*) **Lithium ferrite, $\mathbf{Li_2Fe_2O_4}$,** is anisotropic if prepared below ca 600° C; above this temperature a cubic modification is produced which does not invert on cooling. The curious fact has been observed that its powder lines correspond to a unit containing one molecule. The intensities of these lines are explicable in terms of an NaCl arrangement [XI, (*b*)] of O atoms in (4c) $\frac{1}{2}\frac{1}{2}\frac{1}{2}; 00\frac{1}{2}; 0\frac{1}{2}0; \frac{1}{2}00$ and of Fe and Li atoms irregularly distributed among the positions (4b) $000; \frac{1}{2}\frac{1}{2}0; \frac{1}{2}0\frac{1}{2}; 0\frac{1}{2}\frac{1}{2}$.

(*cl*) Crystals of $\mathbf{NH_4ClO_2}$ are said to have a tetragonal unit holding two molecules. The proposed atomic arrangement places atoms in the following special positions of C_{4v}^2:

NH_4: (a) $00u; \frac{1}{2}\frac{1}{2}u$ with $u=0$
Cl: (b) $0\frac{1}{2}u'; \frac{1}{2}0u'$ with $u'=\frac{1}{4}$
O: (c) $u_1, \frac{1}{2}-u_1, v; u_1+\frac{1}{2}, u_1, v; \bar{u}_1, u_1+\frac{1}{2}, v; \frac{1}{2}-u_1, \bar{u}_1, v$ with $v=\frac{1}{2}$.

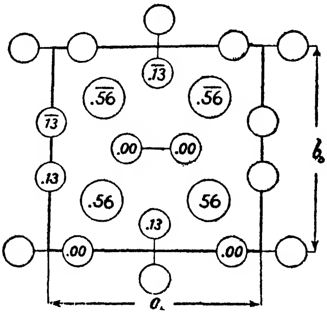
A more detailed study of this structure would be instructive.

(*cm*) The original investigation of $\mathbf{NH_4HF_2}$ (**1932**, 196) gave it the symmetry of V_h^{13} but failed to find an atomic arrangement. Recently the same data have been shown to be consistent with the following structure developed from V_h^7:

N: (g) $\frac{1}{4}\frac{1}{4}u; \frac{1}{4}\frac{3}{4}\bar{u}; \frac{3}{4}\frac{3}{4}\bar{u}; \frac{3}{4}\frac{1}{4}u$ with $u=0.560$
F: (e) $u'00; \bar{u}'00; \frac{1}{2}-u', \frac{1}{2}, 0; u'+\frac{1}{2}, \frac{1}{2}, 0$ with $u'=0.142$
F: (h) $\frac{1}{2}u_1v; \frac{1}{2}\bar{u}_1\bar{v}; 0, \frac{1}{2}-u_1, v; 0, u_1+\frac{1}{2}, \bar{v}$ with $u_1=0.132$, $v=0.135$.

These axes, abc, and X′Y′Z′ of **1930**, 352 are connected by the relations a=X′, b=Z′, c=Y′. The pairs of fluorine atoms belonging to an HF_2 ion are, as should be expected, especially close together with F-F=2.37 A

(Figure 295a and b). It is customary to assume that the hydrogen atom in these acid fluorides lies midway between the two fluorine atoms on a line joining their centers; such an assumption cannot of course be proved by means of X-rays.



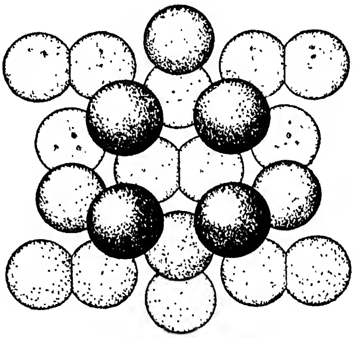


Fig. 295*a*.—(*left*) The structure found for NH_4HF_2 projected upon the c-face of its orthorhombic unit. The larger circles are the NH_4 groups.

Fig. 295*b*.—(*right*) A packing drawing of the NH_4 and HF_2 ions in NH_4HF_2.

(*cn*) **Sodium ferrite** is rhombohedral with the $CsCl_2I$ structure (*d*). Atoms of the single $NaFeO_2$ molecule in the unit rhombohedron have the coordinates: Na at 000; Fe at $\frac{1}{2}\frac{1}{2}\frac{1}{2}$; O at uuu; $\bar{u}\bar{u}\bar{u}$ with u=0.22.

(*co*) From photographic data it has been concluded that the atoms in the two-molecule orthorhombic unit of $\mathbf{NaNO_2}$ are in the following special positions of C_{2v}^{20}:

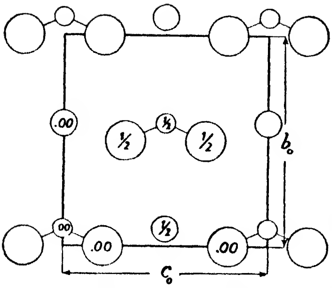
Na: (a) 0u0; $\frac{1}{2}$, u+$\frac{1}{2}$, $\frac{1}{2}$ with u=0.583
N: (a) 0u′0; $\frac{1}{2}$, u′+$\frac{1}{2}$, $\frac{1}{2}$ with u′=0.083
O: (d) $0u_1v$; $0u_1\bar{v}$; $\frac{1}{2}$, $u_1+\frac{1}{2}$, v+$\frac{1}{2}$; $\frac{1}{2}$, $u_1+\frac{1}{2}$, $\frac{1}{2}-v$ with $u_1=0$ and v=0.194.

The coordinates of this description can be derived from those of **1930**, 352, p. 56 by an interchange of Y′ and Z′. The simple structure outlined above is illustrated in Figure 296a and b. The N-O separation in its non-linear NO_2 ion is 1.13 A; the Na-O distance, ca 2.48 A, is substantially that found in $NaNO_3$.

(*cp*) The supposed pseudo-tetragonal unit of $\mathbf{Pb(ClO_2)_2}$ is reported to contain one molecule.

(*cq*) A monoclinic cell for $\mathbf{TlAsS_2}$ with the dimensions of the table would enclose eight molecules. The space group has been given as either C_{2h}^4 or C_{2h}^5.

(*cr*) Photographic observations have been used to assign an atomic arrangement to crystals of **ammonium hypophosphite,** $\mathbf{NH_4H_2PO_2}$. Ac-



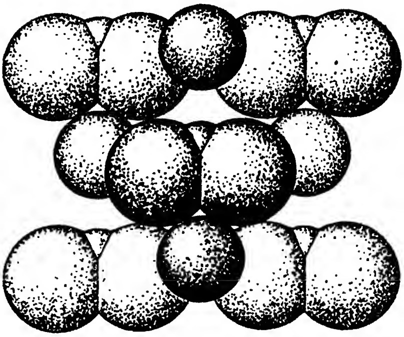
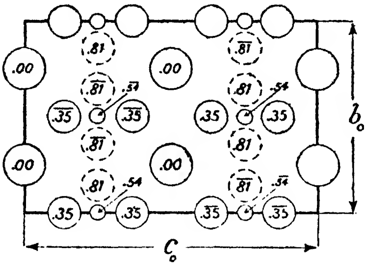


FIG. 296*a*.—(*left*) The orthorhombic grouping found for $NaNO_2$ projected on its a-face. Atoms of the non-linear NO_2 groups are joined by light lines; intermediate circles designate the Na atoms.
FIG. 296*b*.—(*right*) A packing drawing of *a*.



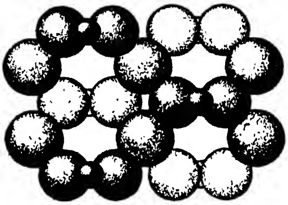


FIG. 297*a*.—(*left*) The structure chosen for $NH_4H_2PO_2$ projected on the a-face of its orthorhombic cell. K, O and P atoms are shown as large, intermediate and small circles. Proposed positions for the hydrogen atoms are indicated by the dashed circles.

FIG. 297*b*.—(*right*) A packing drawing of *a* showing the positions of the NH_4 and PO_2 groups.

cording to this structure (Figure 297) which places four molecules in the orthorhombic unit, atoms are in the following special positions of V_h^{21}:

NH_4: (a) $\pm(0\tfrac{1}{4}0)$; $\pm(0\tfrac{3}{4}\tfrac{1}{2})$ P: (g) $\pm(u0\tfrac{1}{4})$; $\pm(u\tfrac{1}{2}\tfrac{3}{4})$
O: (m) $\pm(u'0v')$; $\pm(u'\tfrac{1}{2}v')$; $\pm(u', 0, \tfrac{1}{2}-v')$; $\pm(u', \tfrac{1}{2}, v'+\tfrac{1}{2})$.

The axes of this description (abc) arise from those of **1930**, 352, p. 67 (X'Y'Z') by transferring the origin to a center of symmetry and using the transformation a=Z', b=X', c=Y'.

The chosen parameters u(P)=0.541, u'(O)=0.347, v'=0.136 give an NH_4-O separation (2.81 A) which is unusually short. This has been considered to show that the NH_4 groups are not rotating; such an interpretation could be convincing only if the correctness of the selected parameters were supported by more quantitative evidence than is now available.

Suggested hydrogen positions, which would bind each atom to two NH_4 groups and one phosphorus atom are (m) u_10v_1; etc. with $u_1=0.805$, $v_1=0.142$; they cannot of course be checked by X-ray observations.

Chapter XVA. Structures of the Type $R_x(MX_3)_y$

(*ab*) The parameters of Table I have been assigned to the atoms in divalent nitrates having the structure (*s*) characteristic of $Ba(NO_3)_2$. It has been suggested (**1931**, 265) that at ordinary temperatures the nitrate groups in $Ca(NO_3)_2$ are rotating but data in support of this idea have not been published.

TABLE I. PARAMETERS FOR CRYSTALS OF THE ALKALINE EARTH NITRATES

Crystal	$u(N)$	$x(O)$	$y(O)$	$z(O)$
$Ba(NO_3)_2$	0.150	0.220	0.204	0.026
$Ca(NO_3)_2$	.161	.247	.207	.033
$Pb(NO_3)_2$	.156	.234	.209	.033
$Sr(NO_3)_2$	.159	.236	.209	.032

(*ac*) The unit prism of **bromlite** (alstonite), $\mathbf{BaCa(CO_3)_2}$, contains two molecules. It is similar in shape to the orthorhombic cells of barite and aragonite with dimensions lying between them. Nevertheless this mineral is thought to be a compound rather than a solid solution.

(*ad*) The monoclinic **barytocalcite**, also $\mathbf{BaCa(CO_3)_2}$, has been assigned a two-molecule unit. The space group is reported as C_2^2.

(*ae*) The three hexagonal carbonates **synchisite,** $\mathbf{CaCO_3 \cdot RFCO_3}$, parisite, $CaCO_3 \cdot 2RFCO_3$, and cordylite, $BaCO_3 \cdot 2RFCO_3$ (R is a mixture of trivalent rare earth atoms, Ce, La, etc.) have unit prisms with bases of about equal size but with very different heights. Closely related atomic arrangements, which however need further confirmation, have been proposed for these minerals. The following atomic coordinates are necessary for their description:

(a) $00w;\ 0, 0, w+\frac{1}{2}$ (b) $00v;\ 00\bar{v};\ 0, 0, v+\frac{1}{2};\ 0, 0, \frac{1}{2}-v$

(c) $\frac{1}{3}\frac{2}{3}u;\ \frac{2}{3}\frac{1}{3}\bar{u};\ \frac{2}{3}, \frac{1}{3}, u+\frac{1}{2};\ \frac{1}{3}, \frac{2}{3}, \frac{1}{2}-u$ (d) $\frac{2}{3}\frac{1}{3}t;\ \frac{1}{3}, \frac{2}{3}, t+\frac{1}{2}$.

Oxygen atoms have not been located; the other atomic positions together with the corresponding parameters (in parentheses) are listed in Table II.

TABLE II. ATOMIC POSITIONS AND PARAMETERS GIVEN TO THE ATOMS IN SYNCHISITE, PARISITE AND CORDYLITE

Substance	*2 Ca (or Ba)*	*2 F*	*2 R*	*2 CO_3*	*4 R*	*4 F*	*4 CO_3*
Synchisite	a	d	a	—	—	—	c
$CaCO_3 \cdot RFCO_3$	(w=0)	($\frac{3}{4}$)	($\frac{1}{4}$)	—	—	—	(−0.117)
Parisite	a	—	—	d	b	c	c
$CaCO_3 \cdot 2RFCO_3$	(0)	—	—	($\frac{1}{4}$)	(0.163)	(0.163)	(−0.076)
Cordylite	a	—	—	d	c	b	c
$BaCO_3 \cdot 2RFCO_3$	(0)	—	—	($\frac{1}{4}$)	($\frac{1}{7}$)	($\frac{1}{7}$)	(−0.07)

(*af*) A new structure has been proposed for **bastnäsite, (Ce, La, . . .) FCO_3**, based on D_{3h}^4 instead of D_{3h}^3. Its atoms have been put in the positions:

6 R: (g) uu0; etc. of **1930**, 352, p. 159, with u=$\frac{2}{3}$
2 F: (a) 000; 00$\frac{1}{2}$ 4 F: (f) $\frac{1}{3}\frac{2}{3}$u; etc. with u=ca 0.
12 O: (i) xyz; etc. with x=y=ca $\frac{1}{3}$, z=ca $\frac{1}{7}$
6 O: (h) uv$\frac{1}{4}$; etc. with u and v undetermined
6 C: (h) u′v′$\frac{1}{4}$; etc. with u′ and v′ undetermined.

(*ag*) Parameters have been determined for the atoms in **KNO_3** and **$PbCO_3$**. As Table III indicates they are almost identical with one another and with those previously found for aragonite (*b*) (see p. 272 of book).

TABLE III. PARAMETERS OF THE ATOMS IN KNO_3, $PbCO_3$ AND ARAGONITE

Atom	*KNO_3*			*$PbCO_3$*			*$CaCO_3$*		
	x	*y*	*z*	*x*	*y*	*z*	*x*	*y*	*z*
K, Pb, Ca	0	0.416	0	0	0.417	0	0	0.417	0
N, C, C	0	.75	$\frac{1}{6}$	0	.764	0.153	0	.75	$\frac{1}{6}$
O(1)	0	.883	$\frac{1}{6}$	0	.908	.153	0	.917	$\frac{1}{6}$
O(2)	0.194	.686	$\frac{1}{6}$	0.205	.692	.153	0.23	.67	$\frac{1}{6}$

(*ah*) A structure based on photographic data has been deduced for the iodine and oxygen atoms in **$LiIO_3$**. These atoms in the two-molecule unit are placed in the following special positions of D_6^6:

I: (c) $\frac{1}{3}\frac{2}{3}\frac{1}{4}$; $\frac{2}{3}\frac{1}{3}\frac{3}{4}$ O: (g) uu0; 0ū0; ū00; ūū$\frac{1}{2}$; 0u$\frac{1}{2}$; u0$\frac{1}{2}$ with u=$\frac{1}{3}$.

If the lithium atoms are in (b) 00$\frac{1}{4}$; 00$\frac{3}{4}$ a reasonable Li-O separation, 2.23 A, is obtained. It should be noticed (Figure 298) that this arrange-

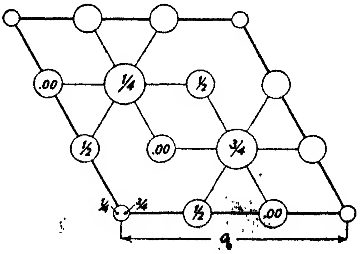


FIG. 298.—A basal projection of the arrangement proposed for $LiIO_3$. The Li atoms are represented by the smallest, the I by the largest circles. The absence of IO_3 ions in this grouping is evident.

TABLE IV. THE CRYSTAL STRUCTURES OF THE COMPOUNDS $R_x(MX_3)_y$

Substance, symmetry and structure type			a_0	c_0 or α	*References*
$AgFO_2$	Tetragonal (?)		5.33	6.08	**1933**, 117.
$BaCO_3$	Ortho-rhombic	KNO_3 (*b*)	5.2556 b_0=8.8345	6.5490	**1931**, 89.
$BaCa(CO_3)_2$ (Bromlite)	Ortho-rhombic	(*ac*)	8.77 b_0=4.99	6.11	**1930**, 111b.
$BaCa(CO_3)_2$ (Barytocalcite)	Monoclinic	(*ad*)	8.15 b_0=5.22, β=83°52′	6.58	**1930**, 111c.
$BaCO_3 \cdot 2RFCO_3$ (Cordylite)	Hexagonal	(*ae*)	4.35	22.8	**1931**, 337.
$BaCeO_3$	Cubic	$CaTiO_3$ (*d*)	4.377		**1934**, 112.
$Ba(NO_3)_2$	Cubic	$Ba(NO_3)_2$ (*s*), (*ab*)			**1931**, 460.
$BaThO_3$	Cubic	$CaTiO_3$ (*d*)	4.480		**1934**, 112.
$BaZrO_3$	Cubic	$CaTiO_3$ (*d*)	4.176		**1934**, 112.
$CaCO_3$ (Calcite)	Hexagonal	(*ap*)			**1931**, 34, 35, 122; **1934**, 283.
$CaCO_3 \cdot RFCO_3$ (Synchisite)	Hexagonal	(*ae*)	4.094	18.20	**1931**, 337.
$CaCO_3 \cdot 2RFCO_3$ (Parisite)	Hexagonal	(*ae*)	4.094	27.93	**1931**, 337.
$CaMg(CO_3)_2$ (Dolomite)	Hexagonal	(*v*)	6.050± 0.004	46°54′	**1930**, 398.
$Ca(NO_3)_2$	Cubic	$Ba(NO_3)_2$ (*s*), (*ab*)			**1931**, 265, 460.
$CaSn(BO_3)_2$ (Nordenskiöldite)	Hexagonal	(*v*)	6.24	45°44′	**1934**, 219.
$CdTiO_3$ (low temp. form)	Hexagonal	$FeTiO_3$ (*ax*)	5.82	53°36′	**1934**, 216.
(Ce, La . . .). FCO_3 (Bastnäsite)	Hexagonal	(*af*)	7.094	9.718	**1931**, 336.
$CoCO_3$	Hexagonal	$NaNO_3$ (*a*)			**1932**, 14.
$CoTiO_3$	Hexagonal	$FeTiO_3$ (*ax*)	5.49	54°42′	**1934**, 216.
$CsNO_3$	Hexagonal	(*aw*)	10.74	7.68	**1934**, 273.
$Cs_2S_2O_6$	Hexagonal	(*au*)	6.326	11.535	**1932**, 187.
$FeCO_3$* (Siderite)	Hexagonal	$NaNO_3$ (*a*)	5.754	47°25′	**1932**, 167.
$FeTiO_3$ (Ilmenite)	Hexagonal	$FeTiO_3$ (*ax*)	5.52	54°50′	**1934**, 14, 216.
H_3BO_3	Triclinic	(*ay*)	7.04 b_0=7.04	6.56†	**1934**, 304.
$InBO_3$	Hexagonal	$NaNO_3$ (*a*)	5.841	48°10′	**1932**, 167.
$KCbO_3$	Cubic (?)	$CaTiO_3$ (*d*)	4.005		**1932**, 371.
KNO_3	Ortho-rhombic	KNO_3 (*b*), (*ag*)	5.43 b_0=9.17	6.45	**1931**, 102.

* 92.5% $FeCO_3$, 6.1% $MnCO_3$.

† For H_3BO_3, α=92°30′, β=101°10′, γ=120°.

Substance, symmetry and structure type			a_0	c_0 or α	*References*
$K_2S_2O_6$	Hexagonal	(*av*)	9.756	6.274	**1931**, 30, 220; **1932**, 186, 201; **1933**, 210, 211.
$KTaO_3$	Cubic (?)	$CaTiO_3$ (*d*)	3.981		**1932**, 371.
$LaBO_3$	Ortho-rhombic	KNO_3 (*b*)	5.10	5.83 b_0=8.22	**1932**, 167.
$LiIO_3$	Hexagonal	(*ah*)	5.469	5.155	**1931**, 499.
$MgTiO_3$	Hexagonal	$FeTiO_3$ (*ax*)	5.54	54°39′	**1934**, 216.
$Mn_3As_2O_6$ (Armangite)	Hexagonal	(*ai*)	13.44	8.72	**1933**, 5.
$MnTiO_3$	Hexagonal	$FeTiO_3$ (*ax*)	5.62	54°16′	**1934**, 216.
NH_4IO_3	Cubic	$CaTiO_3$ (*d*)	4.5		**1932**, 158.
NH_4NO_3 (I) (169.5° to 125.2° C range)	Cubic	(*aj*)	4.40		**1931**, 265; **1932**, 204.
NH_4NO_3 (II) (125.2° to 84.2° C range)	Tetragonal	(*ak*)	5.75	5.00	**1931**, 265; **1932**, 204.
NH_4NO_3 (III) (84.2° to 32.3° C range)	Ortho-rhombic	(*al*)	7.06	5.80 b_0=7.66	**1932**, 204.
NH_4NO_3 (IV) (32.3° to −18° C range)	Ortho-rhombic	(*am*)	5.75	4.96 b_0=5.45	**1932**, 204, 470.
NH_4NO_3 (V) (below −18° C)	Hexagonal	(*an*)	5.75	15.9	**1932**, 204.
$NaCbO_3$	Cubic (?)	$CaTiO_3$ (*d*)	3.889		**1932**, 371.
$NaHCO_3$	Monoclinic	(*ao*)	7.51	3.53 b_0=9.70, β=93°19′	**1933**, 518.
$NaNO_3$	Hexagonal	$NaNO_3$ (*a*), (*ap*)			**1931**, 266; **1932**, 49; **1933**, 492; **1934**, 235.
Na_2SO_3	Hexagonal	(*aq*)	5.441	6.133	**1931**, 500.
$NaSbO_3 \cdot 4BeO$ (Swedenborgite)	Hexagonal	(*y*), (*as*)			**1933**, 3.
$NaTaO_3$	Cubic (?)	$CaTiO_3$ (*d*)	3.881		**1932**, 371.
$NaWO_3$ (Cubic Na-W Bronze)	Cubic	$CaTiO_3$ (*d*), (*ar*)	3.83		**1932**, 250.
$Na_2(WO_3)_5$(?) (Blue Na-W Bronze)	Tetragonal	(*ar*)	17.5	3.80	**1932**, 251.
(Na, Ce, Ca). (Ti, Cb)O_3 (Loparite)	Cubic (?)	$CaTiO_3$ (*d*)	3.854		**1930**, 391.
$NiTiO_3$	Hexagonal	$FeTiO_3$ (*ax*)	5.45	55°8′	**1934**, 216.
$PbCO_3$ (Cerussite)	Ortho-rhombic	KNO_3 (*b*), (*ag*)	5.166	6.146 b_0=8.468	**1933**, 101.
$Pb(NO_3)_2$	Cubic	$Ba(NO_3)_2$ (*s*), (*ab*)			**1931**, 460.
$RbNO_3$	Ortho-rhombic	(*at*)	18.08	7.38 b_0=10.45	**1933**, 351.
$Rb_2S_2O_6$	Hexagonal	$K_2S_2O_6$ (*av*)	10.144	6.409	**1931**, 220; **1932**, 186.
$ScBO_3$	Hexagonal	$NaNO_3$ (*a*)	5.782	48°28′	**1932**, 167.

Substance, symmetry and structure type			a_o	c_o or α	*References*
$SrHfO_3$	Cubic	$CaTiO_3$ (*d*)	4.069		1933, 204.
$Sr(NO_3)_2$	Cubic	$Ba(NO_3)_2$ (*s*), (*ab*)			1931, 460.
$SrZrO_3$	Cubic	$CaTiO_3$ (*d*)	4.089		1933, 204.
YBO_3	Hexagonal	$NaNO_3$ (*a*)	6.44	46°17′	1932, 167.
$ZnCO_3$	Hexagonal	$NaNO_3$ (*a*)	5.669	48°26′	1932, 167.

ment does not provide either simple or complex iodate ions such as would be expected on chemical grounds; instead each iodine atom is made equidistant from six oxygen atoms (I-O=2.23 A=Li-O). For this reason a further study of $LiIO_3$ must sometime be made.

(*ai*) The hexagonal unit of **armangite, $Mn_3As_2O_6$,** recorded in Table IV would contain nine molecules. It is thought that the true unit is probably rhombohedral, with a space group that is C_{3v}^5, D_3^7 or D_{3d}^5.

(*aj*) The **highest** temperature modification of **NH_4NO_3** seems to give the simple diffraction pattern required by a one-molecule cube in which N atoms and NO_3 groups have a body-centered CsCl grouping [XI, (*a*)]. Individual crystals of this modification grow so fast that good intensity data could not be obtained but the single molecule unit has been taken as evidence for a rotating NO_3 group.

(*ak*) The unit of the **second**, tetragonal, form of **NH_4NO_3** contains two molecules. Even at 100° C these crystals grew too fast to yield good diffraction data and no z parameters could be established. The x and y parameters are said to be the following:

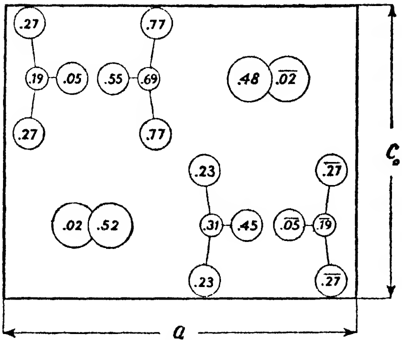
NH_4: $00?; \frac{1}{2}\frac{1}{2}?$ N: $0\frac{1}{2}?; \frac{1}{2}0?$ O: $0\frac{1}{2}?; \frac{1}{2}0?$
O: $xy?; \bar{x}\bar{y}?; \bar{y}x?; y\bar{x}?$ with $x=0.14$, $y=0.36$.

(*al*) The **third** modification of **NH_4NO_3** has a four-molecule orthorhombic prism and a structure based on V_h^{16}. Choosing the same axial orientation that was used for cementite [XIV, (*o*)] atoms have been found to be in the positions:

NH_4: (c) $uv\frac{1}{4}$; etc. (book, p. 266) with $u=0.30$, $v=0.52$
N: (c) $u'v'\frac{1}{4}$; etc. with $u'=-0.09$, $v'=-0.19$
O: (c) $u_1v_1\frac{1}{4}$; etc. with $u_1=-0.19$, $v_1=-0.05$
O: (d) xyz; etc. with $x=-0.07$, $y=-0.27$, $z=0.06$.

This arrangement is illustrated in Figure 299a and b.

(*am*) Two separate determinations have shown that the two molecules in the orthorhombic unit of **NH_4NO_3** which is stable at ordinary temperatures are arranged according to the unusual space group V_h^{13}. With axes chosen as in Table IV they agree in placing atoms in the following special positions:



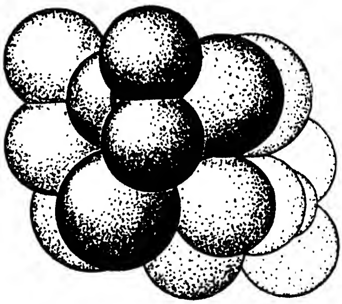


FIG. 299a.—(*left*) The atoms of the third modification of NH_4NO_3 projected on the b-face of its orthorhombic unit. Atoms of the NO_3 groups are joined by light lines.

FIG. 299b.—(*right*) A packing drawing of *a*.

NH_4: (b) $0\frac{1}{2}u$; $\frac{1}{2}0\bar{u}$ N: (a) $00u'$; $\frac{1}{2}\frac{1}{2}\bar{u}'$

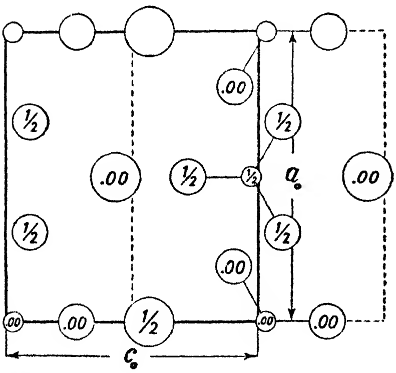
O: (a) $00u_1$; $\frac{1}{2}\frac{1}{2}\bar{u}_1$ O: (f) $w0v$; $\bar{w}0v$; $\frac{1}{2}-w, \frac{1}{2}, \bar{v}$; $w+\frac{1}{2}, \frac{1}{2}, \bar{v}$.

The origin used in **1932**, 470 is displaced one half along the c-axis; therefore though the parameters as listed in Table V are different, the atomic arrangements found in these two investigations are nearly identical. This can be seen from Figure 300a, wherein the unit of **1932**, 204 is outlined by heavy lines, that of **1932**, 470 using dotted lines.

TABLE V. PARAMETERS OF THE ATOMS IN NH_4NO_3

(Room Temperature Form IV)

Determination	$u(NH_4)$	$u'(N)$	$u_1(O)$	w	v
1932, 204	0.57	0.03	0.28	0.19	−0.095
1932, 470	.097	.500	.75	.183	.375



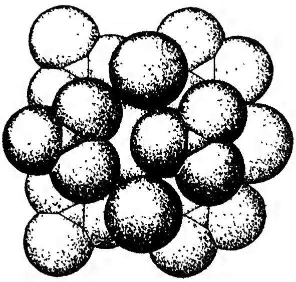


FIG. 300a.—(*left*) The structure of the fourth, room temperature, form of NH_4NO_3 projected on its b-face. The unit cells of the two determinations are indicated by full and by dotted lines. The largest circles are NH_4 ions, the smallest are N atoms.

FIG. 300b.—(*right*) A packing drawing of *a*.

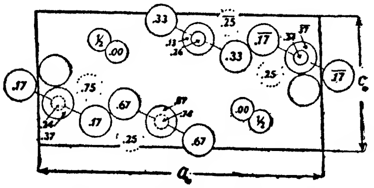
(*an*) The **fifth** modification of **NH_4NO_3** (stable below −18° C) has been given a hexagonal, or pseudo-hexagonal, unit containing six molecules. No X-ray evidence was found which indicated the gradual transition at −60° C.

(*ao*) The monoclinic unit chosen for **$NaHCO_3$** contains four molecules. Using photographic spectral data it has been given an atomic arrangement with all atoms in general positions of C_{2h}^5 (Figure 301): (e) $\pm(xyz)$; $\pm(x+\frac{1}{2}, \frac{1}{2}-y, z+\frac{1}{2})$. The selected parameters are listed in Table VI. In this structure the distance between oxygen atoms in adjacent CO_3 groups is 2.55 A. Such a close approach has been thought to mean that these atoms are bound by an intermediate hydrogen atom which then would be at $x=0.319$, $y=0.250$, $z=0.064$. The atomic parameters of Table VI and with them this evidence for the existence of a hydrogen bond should be confirmed by more quantitative intensity data.

The coordinates used in this description refer to axes so chosen that the gliding component is along the diagonal to two of them. In the conventional description it is along one axis.

TABLE VI. PARAMETERS OF THE ATOMS IN $NaHCO_3$

Atom	*x*	*y*	*z*
Na	0.278	0.0	0.708
C	.069	.236	.314
O(1)	.069	.367	.314
O(2)	.200	.169	.183
O(3)	.939	.169	.444



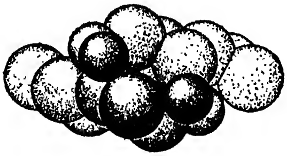


FIG. 301*a*.—(*left*) Atoms in the proposed structure for $NaHCO_3$ projected on the b-face of its monoclinic unit. The large O and small C atoms of the CO_3 groups are joined by light lines; positions thought probable for the hydrogen atoms are indicated by the dotted circles.

FIG. 301*b*.—(*right*) A packing drawing showing the small Na^+ and the larger CO_3 groups of *a*.

(*ap*) X-ray photographs of **$NaNO_3$** made at various temperatures up to 280° C have been interpreted as showing that the NO_3 group is rotating at high temperature. At 280° C the unit rhombohedron has the dimensions $a_0=6.56$ A, $\alpha=45°35'$.

Similar measurements of unit cell size at higher temperatures, as well as Laue photographs up to 600° C, have been made of calcite ($CaCO_3$).

(*aq*) Using data derived from twinned crystals the atoms in the two-molecule unit of **Na_2SO_3** have been placed in the following positions of C_{3i}^1 (Figure 302):

Na: (a) 000 (b) $00\frac{1}{2}$ (d) $\frac{1}{3}\frac{2}{3}u$; $\frac{2}{3}\frac{1}{3}\bar{u}$ with $u=0.67$
S: (d) $\frac{1}{3}\frac{2}{3}u'$; $\frac{2}{3}\frac{1}{3}\bar{u}'$ with $u'=0.17$
O: (g) xyz; $y-x, \bar{x}, z$; $\bar{y}, x-y, z$; $\bar{x}\bar{y}\bar{z}$; $x-y, x, \bar{z}$; $y, y-x, \bar{z}$

with $x=0.14$, $y=0.40$, $z=0.25$.

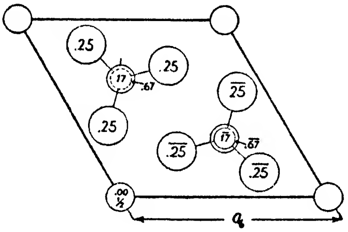


FIG. 302*a*.—(*left*) A basal projection of atoms in the hexagonal unit of Na_2SO_3. The smallest circles are the S and the largest the O atoms.

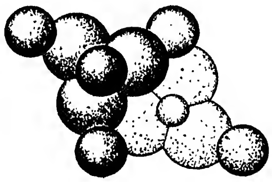


FIG. 302*b*.—(*right*) A packing drawing of *a*. One S atom (at $z=0.\overline{17}$) is shown lying above the plane of its three O atoms.

(*ar*) The analyses of cubic **Na-W bronzes** run from $Na_2W_2O_6$ to apparently $Na_2W_7O_{21}$. This variation in composition is thought due to the gradual replacement of sodium by hydrogen.

Blue Na-W bronzes are made by the weak reduction of $NaWO_3$ by zinc or hydrogen. The composition approaches that stated in Table IV.

(*as*) The formula previously given to the mineral **swedenborgite** is wrong due to the interpretation of its beryllium as aluminum. Its unit contains two of the new molecules $NaSbO_3 \cdot 4BeO$. One or the other of the following two structures developed from C_{6v}^4 has been considered to be correct:

Na: (a) $00u_1$; $0, 0, u_1+\frac{1}{2}$ with $u_1=0$ or
(b) $\frac{1}{3}\frac{2}{3}u'$; $\frac{2}{3}, \frac{1}{3}, u'+\frac{1}{2}$ with $u'=\frac{3}{4}$
O: (b) or (a)
O: (c) $u\bar{u}v$; $2\bar{u}, \bar{u}, v$; $u, 2u, v$; $\bar{u}, u, v+\frac{1}{2}$; $2u, u, v+\frac{1}{2}$;
$\bar{u}, 2\bar{u}, v+\frac{1}{2}$ with $u=\frac{1}{2}$, $v=0$
O: (c) $u''\bar{u}''v''$; etc. with $u''=\frac{1}{6}$ and $v''=\frac{1}{4}$
Sb: (b) $\frac{1}{3}\frac{2}{3}u_2$; $\frac{2}{3}, \frac{1}{3}, u_2+\frac{1}{2}$ with $u_2=\frac{1}{8}$.

(*at*) A reexamination of **$RbNO_3$** has led to a different structure. The large orthorhombic unit of Table IV contains 18 molecules. The crystal, however, is pseudo-hexagonal; if its slight departure from this higher symmetry is neglected, the data are those to be expected from a structure with

$a_0 = 10.45$, $c_0 = 7.38$, having nine molecules in the unit and C_{3v}^2 as space group. The previously chosen unit was rhombohedral (or pseudo-rhombohedral) with an arrangement developed from C_{3v}^5 [see (*n*), p. 279 of book].

(*au*) The unit prism of **$Cs_2S_2O_6$** contains two molecules; the space group is given as either D_6^6 or D_{3h}^4. Cesium and sulfur atoms are assigned to the special positions:

Cs: (a) 000; 00½ Cs: (c) $\frac{1}{3}\frac{2}{3}\frac{1}{4}$; $\frac{2}{3}\frac{1}{3}\frac{3}{4}$
S: (f) $\frac{1}{3}\frac{2}{3}u$; $\frac{2}{3}\frac{1}{3}\bar{u}$; $\frac{2}{3}, \frac{1}{3}, u+\frac{1}{2}$; $\frac{1}{3}, \frac{2}{3}, \frac{1}{2}-u$ with $u = 0.70$.

No X-ray selection could be made between the two sets of oxygen positions that were considered possible.

(*av*) Four studies have been made of the structure of **potassium dithionate, $K_2S_2O_6$**. From them it is clear that the hexagonal unit contains three molecules and that atoms are in the following special positions of D_3^2:

2 S: (c) 00u; 00ū 4 S in 2 sets of: (d) $\frac{1}{3}\frac{2}{3}u$; $\frac{2}{3}\frac{1}{3}\bar{u}$
3 K: (e) uu0; 0ū0; ū00 3 K: (f) uu½; 0ū½; ū0½
18 O in 3 sets of: (g) xyz; $y-x, \bar{x}, z$; $\bar{y}, x-y, z$;
$yx\bar{z}$; $\bar{x}, y-x, \bar{z}$; $x-y, \bar{y}, \bar{z}$.

This crystal provides an instructive example of two very different arrangements (see oxygen parameters) that agree with the qualitative data from a group of spectral photographs. It has been shown that these data are about equally well explained by the two sets of parameters of Table VII. The second set (according to **1932**, 201) gives so short a K-O separation, ca 2.2 A, that it cannot be right. The satisfactory K-O distances, of ca 2.80 A, yielded by the parameters of **1933**, 210 suggest that they may be near the true values (Figure 303a and b).

(*aw*) The hexagonal unit which has been ascribed to **$CsNO_3$** contains nine molecules. No atomic arrangement has been deduced but the curious observation has been made that its powder pattern is nearly identical with that of the cubic (or pseudo-cubic) KIO_3 and very similar to that of the cubic CsI. No change in pattern occurs on heating $CsNO_3$ up to 200° C.

TABLE VII. PARAMETERS FOR THE ATOMS OF $K_2S_2O_6$

Atom	*Parameters according to*					
	1933, 210			**1932**, 201 (*x and y interchanged*)		
	x	*y*	*z*	*x*	*y*	*z*
S(1)	0	0	0.16	0	0	0.16
S(2)	⅓	⅔	.59	⅓	⅔	.59
S(3)	⅓	⅔	.27	⅓	⅔	.27
K(1)	0.375	0.375	0	0.39	0.39	0
K(2)	.69	.69	½	.69	.69	½
O(1)	.165	.11	.23	.09	.18	.22
O(2)	.615	.17	.34	.48	.24	.35
O(3)	.505	.21	.80	.58	.42	.79

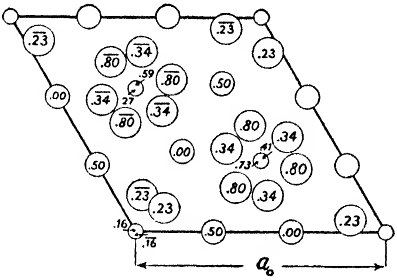


FIG. 303*a*.—(*left*) A basal projection of the atoms in the hexagonal unit of $K_2S_2O_6$. The largest circles are O, the smallest are S atoms.

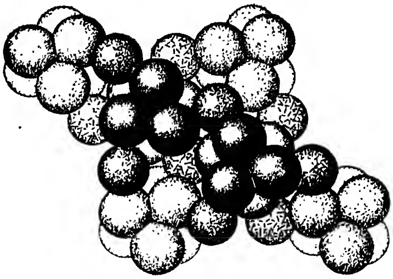


FIG. 303*b*.—(*right*) A packing drawing of *a*. The K ions are indicated by line-shading.

(*ax*) The mineral **ilmenite,** $\mathbf{FeTiO_3}$, has a rhombohedral structure similar to the Fe_2O_3 arrangement [XIII, (*a*)]. Its corresponding space group, C_{3i}^2, is of lower symmetry because of the non-identity of its metal atoms but the two-molecule rhombohedra are of nearly the same size and shape. In $FeTiO_3$, atoms have been given the positions:

Fe: (c) ±(uuu) with u=0.358 Ti: (c) ±(vvv) with v=0.142
O: (f) ±(xyz); ±(yzx); ±(zxy) with x=0.555, y=−0.055, z=0.250.

As might be expected from the close similarity in their cell sizes, it has been found that ilmenite and Fe_2O_3 form a continuous series of solid solutions (**1934**, 216).

Nickel titanate, $NiTiO_3$, has the ilmenite structure. The parameters assigned to its atoms are identical, within the limit of experimental error, with those of $FeTiO_3$.

Cadmium titanate, $CdTiO_3$, occurs in two forms. The previously described structure, isomorphous with $CaTiO_3$ (*d*), is found in material prepared by quenching from above 1000° C. Crystals made below this temperature are like $FeTiO_3$. The parameters given their atoms, u(Cd)=0.342, v(Ti)=0.156, x=0.54, y=−0.03, z=0.26, yield the short Cd-O distance of 2.24 A but it is said that other values would make it shorter still.

(*ay*) The triclinic cell chosen for crystals of **boric acid,** $\mathbf{H_3BO_3}$, includes four molecules. If the space group is C_i^1, as is undoubtedly the case, all atoms are in general positions ±(xyz). Boron and oxygen atoms have been assigned parameters (Table VIII) which yield a thoroughly platy structure. The resulting interatomic distances are B-O=1.36 A and, between adjacent groups, O-O=2.71 A. It is stated that this O-O separation is sufficiently below the normal 2.80 A to show that hydrogen atoms are situated between them. Inasmuch as the entire determination of structure, involving many variable parameters, has been based on

TABLE VIII. PARAMETERS FOR THE ATOMS OF H_3BO_3

Atom	x	y	z
B(1)	0.653	0.430	0.25
B(2)	.319	.764	.25
O(1)	.430	.319	.25
O(2)	.764	.319	.25
O(3)	.764	.653	.25
O(4)	.208	.542	.25
O(5)	.208	.875	.25
O(6)	.542	.875	.25

qualitative visual estimates of photographic intensities, it is hard to attach much significance to this argument. In several instances unexpectedly short interatomic distances have been ascribed to hydrogen bonds rather than to errors or inaccuracies in parameter determinations. It should be pointed out that, except with certain especially favorable crystals (such as the alkali acid fluorides), intensity data better than the usual qualitative estimates on simple reflections are needed to fix parameters with enough certainty to provide real evidence for such bonds.

(*ac*) The unimolecular tetragonal cell of **β-Ag_2HgI_4** has atoms in the following special positions of V_d^1 (Figure 304a and b):

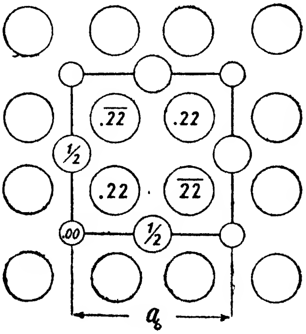
Hg: (a) 000 Ag: (f) $0\frac{1}{2}\frac{1}{2}$; $\frac{1}{2}0\frac{1}{2}$
I: (n) uuv; $u\bar{u}\bar{v}$; $\bar{u}u\bar{v}$; $\bar{u}\bar{u}v$ with u=0.27, v=0.225.

The form of Cu_2HgI_4 stable at room temperature has the same structure with u=0.255, v=0.275.

(*ad*) The α-modification of **Ag_2HgI_4**, stable above 50° C, is said to be truly cubic. The arrangement in the low temperature form (*ac*) is a distortion of the ZnS structure; this α-structure is described as an exact ZnS grouping [XI, (*c*)] with three-fourths of the positions (4b) 000; $\frac{1}{2}\frac{1}{2}0$; $\frac{1}{2}0\frac{1}{2}$; $0\frac{1}{2}\frac{1}{2}$ occupied by an irregular distribution of Hg+2 Ag.

The α-form of Cu_2HgI_4, stable above 70° C, is like the silver salt.

(*ae*) Three studies have been made of the structure of anhydrous **sodium sulfate, Na_2SO_4**. They agree in choosing an eight-molecule unit and in selecting V_h^{24} as corresponding space group. The atomic arrange-



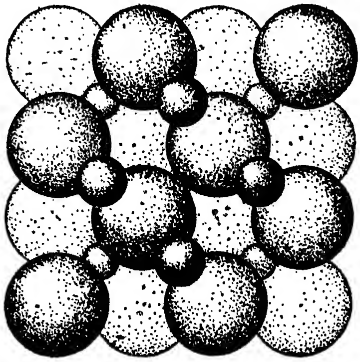


FIG. 304*a*.—(*left*) A c-face projection of atoms of the room temperature (β) modification of Ag_2HgI_4. Atoms of I are represented by the largest, of Hg by the smallest circles.

FIG. 304*b*.—(*right*) A packing drawing of *a* with the atoms given their usual ionic sizes.

TABLE I. THE CRYSTAL STRUCTURES OF THE COMPOUNDS $R_x(MX_4)_y$

Substance, symmetry and structure type			a_0	c_0 or α	*References*
β-Ag_2HgI_4	Tetragonal	Ag_2HgI_4 (*ac*)	6.340	6.340	1931, 257.
α-Ag_2HgI_4 (stable above 50° C)	Cubic	(*ad*)	6.383		1934, 133.
$AgIO_4$	Tetragonal	$CaWO_4$ (*d*)	5.368	12.013	1932, 51.
$AgReO_4$	Tetragonal	$CaWO_4$ (*d*)	5.349	11.916	1933, 81.
Ag_2SO_4	Ortho-rhombic	Na_2SO_4 (*ae*)	5.847 b_0=12.659	10.251	1931, 179; 1932, 492.
Ag_5SbS_4 (Stephanite)	Ortho-rhombic	(*af*)	7.85 b_0=12.48	8.58	1932, 394.
Ag_2SeO_4	Ortho-rhombic	Na_2SO_4 (*ae*)	6.069 b_0=12.815	10.211	1931, 179.
$BAsO_4$	Tetragonal	BPO_4 (*ag*)	4.459	6.796	1933, 421; 1934, 240.
BPO_4	Tetragonal	BPO_4 (*ag*)	4.334	6.636	1933, 421; 1934, 240.
$BaWO_4$	Tetragonal	$CaWO_4$ (*d*), (*ah*)	5.64	12.70	1931, 344; 1932, 247.
$BeNaPO_4$ (Beryllonite)	Monoclinic	(*ba*)	8.13 b_0=7.76, β=90°	14.17	1934, 86.
$CaCrO_4$	Tetragonal	$ZrSiO_4$ (*f*), (*ai*)	7.25	6.34	1930, 381; 1932, 106.
Ca(F, Cl)$Ca_4(PO_4)_3$ (Apatite)	Hexagonal	(*aj*)			1930, 426; 1931, 298, 380; 1932, 203.
CaMg(OH)AsO_4 (Adelite)	Ortho-rhombic	(*ay*)	5.88 b_0=8.85	7.43	1933, 7.
CaMg(OH)AsO_4 (Tilasite)	Monoclinic	(*ay*)	5.68 b_0=8.63, β=91°28′	7.57	1933, 7.
$CdCr_2S_4$	Cubic	$MgAl_2O_4$ (*k*)	10.190		1931, 347.
$CdFe_2O_4$	Cubic	$MgAl_2O_4$ (*k*)	8.45		1931, 116.
$CoAl_2O_4$	Cubic	$MgAl_2O_4$ (*k*), (*ak*)	8.101		1931, 269; 1932, 30.
(Co, Ni)$_3S_4$ (Linneite)	Cubic	$MgAl_2O_4$ (*k*)	9.41 (for several minerals)		1931, 318.
$CoSO_4$	Ortho-rhombic*		4.65 b_0=6.71	8.45	1931, 209.
Co_2TiO_4	Cubic	$MgAl_2O_4$ (*k*)	8.420		1930, 246c; 1931, 212.
$CsOsNO_3$	Ortho-rhombic	(*al*)	8.08 b_0=8.35	7.22	1932, 239, 241.
$CsReO_4$	Ortho-rhombic	(*am*)	5.73 b_0=5.98	14.26	1933, 222.
$Cs_2S_2O_8$	Monoclinic	(*bb*)	8.13 b_0=8.33, β=95°19′	6.46	1934, 306.
$CuAl_2O_4$	Cubic	$MgAl_2O_4$ (*k*)	8.064‡		1931, 269; 1932, 223.
Cu_3AsS_4 (Enargite)	Ortho-rhombic	(*an*)	6.46 b_0=7.43	6.18	1933, 463; 1934, 208.
$CuFe_2O_4$ (quenched)	Cubic	$MgAl_2O_4$ (*k*), (*ak*)			1934, 281.

* This unit contains four molecules.

‡ The other determination (1931, 269) gives a_0=8.074 A.

Substance, symmetry and structure type			a_0	c_0 *or* α	*References*
$CuFe_2O_4$ (annealed)	Tetragonal	(*ak*)	8.28	8.68	**1934**, 281.
Cu_2FeSnS_4 (Stannite)	Tetragonal	(*bd*)	5.46	10.725	**1923**, 64; **1934**, 318.
β-Cu_2HgI_4	Tetragonal	Ag_2HgI_4 (*ac*)	6.08	6.135	**1931**, 257.
α-Cu_2HgI_4 (stable above 70° C)	Cubic	(*ad*)	6.103		**1934**, 133.
Cu_3VS_4 (Sulvanite)	Cubic	(*u*), (*ao*)	5.370		**1933**, 350.
$FeAl_2O_4$	Cubic	$MgAl_2O_4$ (*k*), (*ak*)	8.119*		**1931**, 80, 269; **1932**, 30.
$FeCr_2O_4$	Cubic	$MgAl_2O_4$ (*k*)	8.344		**1931**, 80.
(Fe, Mg)Cr_2O_4 (Chromite)	Cubic	$MgAl_2O_4$ (*k*), (*ap*)			**1932**, 104.
Fe_3O_4 (Magnetite)	Cubic	$MgAl_2O_4$ (*k*), (*aq*)	8.374		**1931**, 80; **1932**, 345; **1934**, 77.
Fe_2TiO_4	Cubic	$MgAl_2O_4$ (*k*), (*ak*)	8.50		**1932**, 30.
FeV_2O_4	Cubic	$MgAl_2O_4$ (*k*)			**1932**, 302.
Ga_2ZnO_4	Cubic	$MgAl_2O_4$ (*k*)	8.323		**1931**, 75.
KBF_4	Orthorhombic	$BaSO_4$ (*a*)	7.84	7.38 $b_0=5.68$	**1930**, 436.
$KClO_4$ (low)	Orthorhombic	$BaSO_4$ (*a*), (*ar*)	8.834	7.240 $b_0=5.650$	**1931**, 404; **1932**, 177.
K_2CrO_4	Orthorhombic	K_2SO_4 (*m*), (*as*)	5.92	7.61 $b_0=10.40$	**1931**, 88, 501.
$K_2Mg_2(SO_4)_3$ (Langbeinite)	Cubic	(*at*)	9.96		**1931**, 134.
$KMnO_4$	Orthorhombic	$BaSO_4$ (*a*), (*ar*)	9.09	7.41 $b_0=5.72$	**1931**, 306.
$KOsNO_3$	Tetragonal	$CaWO_4$ (*d*), (*ah*)	5.65	13.08	**1932**, 240, 241.
Li(Fe, Mn)PO_4 (Triphylite)	Orthorhombic	(*au*)	4.67	6.00 $b_0=10.34$	**1932**, 175.
Li_3PO_4	Orthorhombic	(*au*)	4.86	6.07 $b_0=10.26$	**1932**, 495.
Li_2SO_4	Monoclinic	(*av*)	8.25	8.44 $b_0=4.95$, $\beta=107°54'$	**1932**, 5a.
$MgAl_2O_4$ (Spinel)	Cubic	$MgAl_2O_4$ (*k*), (*ak*)	8.059± 0.004		**1931**, 80, 286; **1932**, 101, 165, 286; **1934**, 51.
$MgCr_2O_4$	Cubic	$MgAl_2O_4$ (*k*)	8.305		**1931**, 80.
$MgFe_2O_4$	Cubic	$MgAl_2O_4$ (*k*), (*ak*)	8.366		**1931**, 33, 80, 270; **1932**, 30.
$MgGa_2O_4$	Cubic	$MgAl_2O_4$ (*k*), (*ak*)	8.279		**1931**, 33; **1932**, 30, 198, 295.

* In **1931**, 269, $a_0=8.084$ A.

Substance, symmetry and structure type			a_0	c_0 *or* α	*References*
$MgIn_2O_4$	Cubic	$MgAl_2O_4$ (*k*), (*ak*)	8.81		**1932**, 30.
Mg_2TiO_4	Cubic	$MgAl_2O_4$ (*k*), (*ak*)	8.44		**1931**, 212; **1932**, 30.
$MnAl_2O_4$	Cubic	$MgAl_2O_4$ (*k*), (*ak*)	8.271		**1931**, 80, 269; **1932**, 30.
$MnCr_2O_4$	Cubic	$MgAl_2O_4$ (*k*)	8.436		**1931**, 80.
$MnCr_2S_4$	Cubic	$MgAl_2O_4$ (*k*)	10.045		**1931**, 347.
$MnFe_2O_4$	Cubic	$MgAl_2O_4$ (*k*)	8.457		**1931**, 80.
Mn_2TiO_4	Cubic	$MgAl_2O_4$ (*k*)	8.67		**1931**, 212.
$(NH_4)_2BeF_4$	Orthorhombic	K_2SO_4 (*m*), (*as*)	5.8	7.5 $b_0=10.2$	**1934**, 114.
NH_4ClO_4 (low)	Orthorhombic	$BaSO_4$ (*a*), (*ar*)	9.202	7.449 $b_0=5.816$	**1931**, 404; **1932**, 177.
$(NH_4)_2CrO_4$	Monoclinic	(*aw*)	6.15	7.66 $b_0=6.27$, $\beta=115°13'$	**1931**, 73.
NH_4OsNO_3	Orthorhombic	(*ax*)	5.53	13.54 $b_0=5.86$	**1932**, 238, 241.
$(NH_4)_2S_2O_8$	Monoclinic	(*bb*)	7.83	6.13 $b_0=8.04$, $\beta=95°9'$	**1934**, 306.
Na_2SO_4	Orthorhombic	Na_2SO_4 (*r*), (*ae*)	5.85	9.75 $b_0=12.29$	**1931**, 87; **1932**, 493.
$NiAl_2O_4$	Cubic	$MgAl_2O_4$ (*k*), (*ak*)	8.050		**1931**, 269; **1932**, 30.
$NiCr_2O_4$	Cubic	$MgAl_2O_4$ (*k*)	8.30		**1932**, 224.
$Pb_{10}Cl_2(AsO_4)_6$ (Mimetite)	Hexagonal	(*aj*)			**1932**, 203.
$Pb_{10}Cl_2(PO_4)_6$ (Pyromorphite)	Hexagonal	(*aj*)			**1932**, 203.
$Pb_{10}Cl_2(VO_4)_6$ (Vanadinite)	Hexagonal	(*aj*)			**1932**, 203.
$PbCrO_4$ (Krokoite)	Monoclinic	(*i*)	7.10	6.80 $b_0=7.40$, $\beta=102°27'$	**1931**, 63.
$PbZn(OH)VO_4$ (Descloizite)	Orthorhombic	(*az*)	6.05	7.56 $b_0=9.39$	**1933**, 24.
$RbOsNO_3$	Orthorhombic	(*ax*)	5.57	13.64 $b_0=5.84$	**1932**, 238, 241.
$RbReO_4$	Tetragonal	$CaWO_4$ (*d*)	5.80	13.17	**1933**, 222.
$TlOsNO_3$	Orthorhombic	(*ax*)	5.42	13.45 $b_0=5.68$	**1932**, 238, 241.
$TlReO_4$	Orthorhombic	(*am*)	5.63	13.33 $b_0=5.80$	**1932**, 222.
YVO_4	Tetragonal	$ZrSiO_4$ (*f*)	7.126	6.197	**1933**, 75.
$ZnAl_2O_4$	Cubic*	$MgAl_2O_4$ (*k*), (*ak*)	8.062		**1931**, 80, 269; **1932**, 30, 165, 198.
$ZnCr_2O_4$	Cubic	$MgAl_2O_4$ (*k*)	8.296		**1931**, 80.
$ZnCr_2S_4$	Cubic	$MgAl_2O_4$ (*k*)	9.92		**1931**, 318.
$ZnFe_2O_4$	Cubic	$MgAl_2O_4$ (*k*)	8.423		**1931**, 80.

* In **1931**, 269 and **1932**, 198, $a_0=8.093$ A.

Substance, symmetry and structure type			a_0	c_0 or α	*References*
$ZnSO_4$	Ortho-rhombic	(*bc*)	8.58	4.76 b_0=6.73	**1934**, 237.
Zn_2SnO_4	Cubic	$MgAl_2O_4$ (*k*), (*ak*)	8.61		**1932**, 30.
Zn_2TiO_4	Cubic	$MgAl_2O_4$ (*k*)	8.410		**1930**, 246c; **1931**, 212.

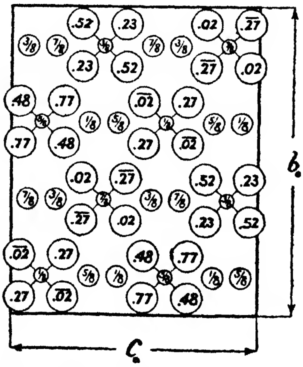
ments proposed in the first two investigations are obviously wrong since they are chemically unreasonable, give unsatisfactory interatomic distances and fail to agree with observed intensities of reflection. The most recent structure (**1932**, 493), illustrated in Figure 305a and b, meets these requirements, the data being drawn from spectral photographs. Transferring the origin of **1930**, 352, p. 69 to a center of symmetry at $\frac{1}{8}\frac{1}{8}\frac{1}{8}$, atoms are in the following positions:

8 S: (a) $\pm(\frac{1}{8}\frac{1}{8}\frac{1}{8})$ and 6 similar points about $0\frac{1}{2}\frac{1}{2}$, $\frac{1}{2}\frac{1}{2}0$ and $0\frac{1}{2}0$

16 Na: (g) $\pm(\frac{1}{8}\frac{1}{8}u)$; $\pm(\frac{1}{8}, \frac{1}{8}, \frac{1}{4}-u)$ and 12 similar points about $0\frac{1}{2}\frac{1}{2}$, $\frac{1}{2}\frac{1}{2}0$, $\frac{1}{2}0\frac{1}{2}$ with u=0.436

32 O: (h) $\pm(xyz)$; $\pm(x, \frac{1}{4}-y, \frac{1}{4}-z)$; $\pm(\frac{1}{4}-x, y, \frac{1}{4}-z)$; $\pm(\frac{1}{4}-x, \frac{1}{4}-y, z)$ and 24 similar points about $0\frac{1}{2}\frac{1}{2}$, $\frac{1}{2}\frac{1}{2}0$, $\frac{1}{2}0\frac{1}{2}$ with x=−0.022, y=0.056, z=0.214.

Silver sulfate, Ag_2SO_4, and the corresponding selenate, Ag_2SeO_4, are isomorphous with Na_2SO_4. The structure given them from a study of their photographic reflections is not like that outlined above and yields improbable interatomic distances. It has since been shown that these data are explicable in terms of the Na_2SO_4 structure with the following slightly different parameters for Ag_2SO_4: u(Ag)=0.450, x=0.022, y=0.058, z=0.208.



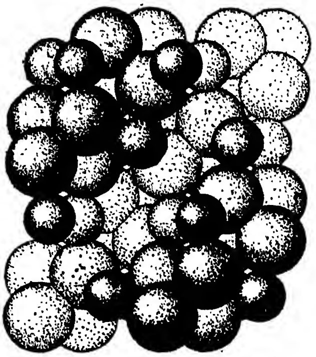


FIG. 305*a*.—(*left*) Atoms in the orthorhombic arrangement found for Na_2SO_4 projected on an a-face. The atoms forming the SO_4 ions are joined by light lines.

FIG. 305*b*.—(*right*) A packing drawing of the Na^+ and SO_4^{--} ions in Na_2SO_4.

(*af*) The cell of **stephanite, Ag_5SbS_4,** contains four molecules; its space group is said to be V_h^{17}.

(*ag*) The tetragonal cells of **BPO_4** and **$BAsO_4$** are bimolecular. According to a structure developed from S_4^2 they have atoms in the following positions:

B: (c) $0\frac{1}{2}\frac{1}{4}$; $\frac{1}{2}0\frac{3}{4}$ P (or As): (a) 000; $\frac{1}{2}\frac{1}{2}\frac{1}{2}$

O: (g) xyz; $\bar{y}x\bar{z}$; $\bar{x}\bar{y}z$; $y\bar{x}\bar{z}$;
$x+\frac{1}{2}, y+\frac{1}{2}, z+\frac{1}{2}$; $\frac{1}{2}-y, x+\frac{1}{2}, \frac{1}{2}-z$; $\frac{1}{2}-x, \frac{1}{2}-y, z+\frac{1}{2}$; $y+\frac{1}{2}, \frac{1}{2}-x, \frac{1}{2}-z$.

For BPO_4, $x=0.138$, $y=0.260$, $z=0.131$; for $BAsO_4$, $x=0.160$, $y=0.260$, $z=0.140$. This arrangement, as a distortion of the high cristobalite grouping [XII, (*ae*), (*bd*)], consists of linked BO_4 and P (or As) O_4 tetrahedra (Figure 306a and b).

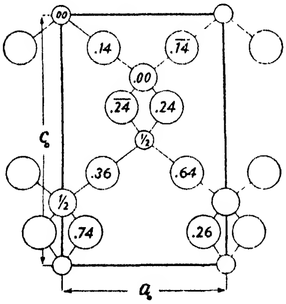


FIG. 306*a*.—(*left*) Atoms of the structure chosen for BPO_4 projected on one of the a-faces of its tetragonal cell. The smallest circles are P, the intermediate circles B atoms.

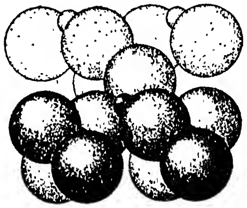


FIG. 306*b*.—(*right*) A packing drawing of *a*. The O atoms have their ionic radius; the size of the B atom is without significance.

(*ah*) Every study of crystals with the $CaWO_4$ (*d*) arrangement has resulted in different oxygen parameters. A new set, for $BaWO_4$, is $x=0.20$, $y=0.46$, $z=0.32$.

Potassium osmiamate, $KOsNO_3$, is reported to have this structure with N and O atoms indistinguishable from one another. The parameters chosen for these atoms are $x=0.23$, $y=0.05$, $z=-0.065$.

(*ai*) The positions found for the oxygen atoms in **$CaCrO_4$** are those established in other crystals having the zircon grouping (*f*): $u=0.17$, $v=0.34$.

(*aj*) X-ray measurements have been made upon a number of substances with structures like **apatite, $Ca(F, Cl)Ca_4(PO_4)_3$,** (*z*). The hexagonal unit prisms found in this way are recorded in Table II.

In the apatite arrangement (*z*) fluorine atoms are in (a) $00\frac{1}{4}$; $00\frac{3}{4}$. Another possible pair of positions, which could not be rigorously excluded by the observed intensities, would place them in the larger holes (b) 000; $00\frac{1}{2}$. It has been shown that in the lead compounds, $Pb_{10}Cl_2(MO_4)_6$, where M=P or As, packing requires that the chlorine atoms must be in these alternative positions (b). Parameters chosen to give suitable packing throughout the structure for these two crystals and for the chlor-X-apatite of Table II are listed in Table III. The previously found values for apatite itself are included for comparison.

TABLE II. UNIT CELLS OF APATITE-LIKE SUBSTANCES

Name	*Formula*	a_0	c_0
Apatite	$Ca_{10}(F, Cl)_2(PO_4)_6$	9.36	6.85
Chlor-X-Apatite	$Ca_{10}(Cl, X)_2(PO_4)_6$	9.52	6.85
Pyromorphite	$Pb_{10}Cl_2(PO_4)_6$	9.95 9.95	7.31 7.32
Mimetite	$Pb_{10}Cl_2(AsO_4)_6$	10.24 10.36	7.43 7.52
Vanadinite	$Pb_{10}Cl_2(VO_4)_6$	10.31 10.47	7.34 7.43
Hydroxy-Apatite	$Ca_{10}(OH)_2(PO_4)_6$	9.40	6.93
Tricalcium Phosphate Hydrate	$Ca_9(H_2O)_2(PO_4)_6$	9.25	6.88
Oxy-Apatite	$Ca_{10}O(PO_4)_6$	9.38	6.93
Bone (Naptha extracted)		9.27	6.95

TABLE III. PARAMETERS IN APATITE AND RELATED CRYSTALS

	Apatite			*Pyromorphite*			*Mimetite*			*Chlor-X-Apatite*		
Atom	*x*	*y*	*z*	*x*	*y*	*z*	*x*	*y*	*z*	*x*	*y*	*z*
F, Cl	0	0	$\frac{1}{4}$	0	0	0	0	0	0	0	0	0
Ca, Pb(1) (f)	$\frac{1}{3}$	$\frac{2}{3}$	0	$\frac{1}{3}$	$\frac{2}{3}$	0	$\frac{1}{3}$	$\frac{2}{3}$	0	$\frac{1}{3}$	$\frac{2}{3}$	0
Ca, Pb(2) (h)	$\frac{1}{4}$	0	$\frac{1}{4}$	$\frac{1}{4}$	0.003	$\frac{1}{4}$	$\frac{1}{4}$	0	$\frac{1}{4}$	$\frac{1}{4}$	0	$\frac{1}{4}$
P, As (h)	0.416	0.361	$\frac{1}{4}$	0.417	.369	$\frac{1}{4}$	0.411	0.392	$\frac{1}{4}$	0.417	0.361	$\frac{1}{4}$
O(1) (h)	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{4}$	.344	.480	$\frac{1}{4}$	.317	.458	$\frac{1}{4}$	.333	.500	$\frac{1}{4}$
O(2) (h)	.60	.466	$\frac{1}{4}$	.600	.464	$\frac{1}{4}$	.644	.503	$\frac{1}{4}$	.600	.467	$\frac{1}{4}$
O(3)	$\frac{1}{3}$	$\frac{1}{4}$	0.062	.350	.250	0.063	.336	.272	0.061	.333	.250	0.063

(*ak*) Unexpected intensities are observed from a number of compounds which obviously have the **spinel**, $MgAl_2O_4$, structure (*k*). Two explanations have been offered: one is that the metal atoms are distributed haphazardly among all the metal positions, both (8f) and (16c); the other considers that half of the sixteen chemically alike atoms are in (8f) and that the rest together with the eight chemically alike metal atoms are irregularly distributed throughout (16c). The latter has been called an "equipoint" structure. Qualitative estimates of intensity do not seem to conflict with the second interpretation but more quantitative observations and calculations are needed for final confirmation. Accurate parameters have been found for the oxygen atoms in several compounds. These additional data are collected in Table IV.

Cupric ferrite, $CuFe_2O_4$, when quenched, is cubic with the spinel structure; if it is slowly cooled or annealed at 350° C for some time its pattern is said to be that of the tetragonal cell of Table I.

TABLE IV. TYPE AND PARAMETER FOUND FOR SEVERAL SPINEL STRUCTURES

Type		*Parameter*
Normal	*"Equipoint"*	*u*
$CoAl_2O_4$		0.390
$FeAl_2O_4$		.390
	$FeTiFeO_4$	.390
$MgAl_2O_4$		.390
	$FeMgFeO_4$	.390
	$GaMgGaO_4$	.392
	$InMgInO_4$	.372
	$MgTiMgO_4$	.390
$MnAl_2O_4$		.390
$NiAl_2O_4$		.390
$ZnAl_2O_4$		.390
	$ZnSnZnO_4$	.390

(*al*) The unit prism of **$CsOsNO_3$** contains four molecules. Its Cs and Os atoms are said to be in the following positions of V^2:

Os: (c) $0u\frac{1}{4}$; $0\bar{u}\frac{3}{4}$ and (d) $\frac{1}{2}u'\frac{1}{4}$; $\frac{1}{2}\bar{u}'\frac{3}{4}$ with $u=u'=\frac{1}{8}$
Cs: (e) xyz; $x\bar{y}\bar{z}$; $\bar{x}, y, \frac{1}{2}-z$; $\bar{x}, \bar{y}, z+\frac{1}{2}$ with $x=\frac{1}{4}$, $y=\frac{5}{8}$, $z=\frac{1}{4}$.

(*am*) Four molecules are included in the pseudo-tetragonal orthorhombic cells of **$CsReO_4$** and **$TlReO_4$**. The space group has been given as V_h^{16}.

(*an*) Two differing determinations have been made of the structure of **enargite, Cu_3AsS_4**. According to one the atoms of its single molecule cell are all in positions (g) of the orthorhombic space group V_h^{12}. Sulfur atoms are in one set of these special positions, copper and arsenic atoms, grouped together, in another.

The unit prism of the other and presumably correct arrangement (see Table I) is twice as high in the direction of the b-axis, i.e. $b_0=7.43$ A. The atoms in the bimolecular unit are distributed according to the following cases of C_{2v}^7:

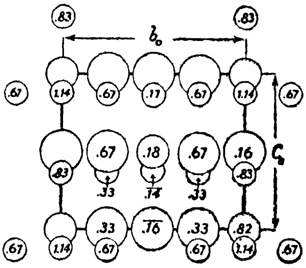
(a) $u0v$; $\bar{u}, \frac{1}{2}, v+\frac{1}{2}$ (b) xyz; $\bar{x}, \frac{1}{2}-y, z+\frac{1}{2}$; $\bar{x}, y+\frac{1}{2}, z+\frac{1}{2}$; $x\bar{y}z$

with the parameters listed in Table V. The axes of this description differ from those of **1930**, 352 by an interchange of X′ and Y′. Like so many

TABLE V. PARAMETERS OF THE ATOMS IN Cu_3AsS_4

Atom	*No. per cell*	*Positions*	*x*	*y*	*z*
As	2	(a)	0.820	0	0
Cu(1)	2	(a)	.165	0	0.500
Cu(2)	4	(b)	.333	0.245	.990
S(1)	2	(a)	.830	0	.360
S(2)	2	(a)	.140	0	.875
S(3)	4	(b)	.330	.255	.367

other sulfides this grouping is a system of sulfur tetrahedra linked by sharing corners and having metal atoms at their centers. As Figure 307b shows, the packing is excellent if the crystal is assumed to be made up of neutral atoms (As-S=2.21 A, Cu-S=2.31 A).



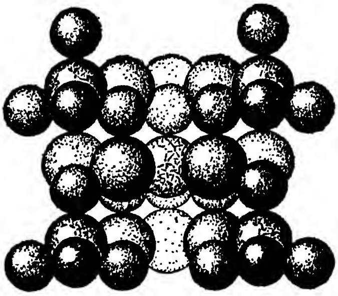


FIG. 307*a*.—(*left*) The orthorhombic unit of enargite, Cu_3AsS_4, projected on its a-face. The small circles are S, the largest circles are Cu atoms.

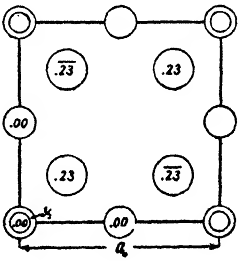
FIG. 307*b*.—(*right*) A packing drawing of Cu_3AsS_4 giving the atoms their neutral radii. Atoms of As are line-shaded.

(*ao*) A new and simpler structure has been found for **sulvanite, Cu_3VS_4**. With a cube edge half that previously chosen, the unimolecular cell has atoms in the following positions of T_d^1 (Figure 308):

V: (1a) 000 Cu: (3b) $\frac{1}{2}00$; $0\frac{1}{2}0$; $00\frac{1}{2}$
S: (4a) uuu; $u\bar{u}\bar{u}$; $\bar{u}u\bar{u}$; $\bar{u}\bar{u}u$ with u=0.235.

This leads to a V-S separation of 2.18 A; the Cu-S distance is 2.28 A.

FIG. 308.—A cube face projection of the atoms in the new grouping established for sulvanite, Cu_3VS_4. The smallest circles are V, the largest S atoms.



(*ap*) The edge lengths of the unit cube of several chromites, (Fe, Mg). (Cr, Al)$_2$O$_4$, have been measured. These lengths increase with the Cr_2O_3 content.

(*aq*) Powder photographs of magnetite, Fe_3O_4, made at various temperatures down to ca −170° C prove that the anomalous heat effect found at −160° C is not due to a change in structure. Like MnO, Fe_3O_4 is, however, reported to have a region in which it shrinks on being warmed (see Table II, Chapter XIA).

(*ar*) Positions have been assigned to all the atoms in three substances, **$KMnO_4$**, **$KClO_4$** and **NH_4ClO_4**, with the barite, $BaSO_4$, structure (*a*). These crystals have units which are almost identical in size and it is probable that their real atomic positions are practically the same. Nevertheless the structures proposed for the permanganate and for the perchlorates show important differences (Figures 309 and 310). The $KMnO_4$ determination rests on photographic spectral data; the observations on $KClO_4$ and NH_4ClO_4 are more quantitative spectrometric measurements. It is, however, difficult to be sure of the deductions from the latter results. The published parameters are obviously wrong: they correspond to an utterly impossible grouping. If the drawing of the perchlorate paper (**1932**, 177) is assumed to be correct and the parameters are altered to fit it, a structure is obtained which yields the interatomic distances stated in the paper and which therefore is probably the intended one. These parameters, and the values for $KMnO_4$ expressed in terms of a unit with

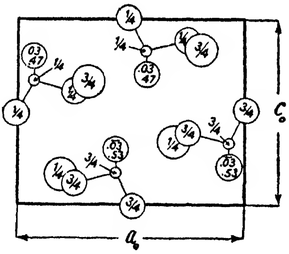


FIG. 309.—(*left*) The unit cell of the orthorhombic structure found for $KMnO_4$ projected on its b-face. Atoms of the MnO_4 ions are connected by light lines.

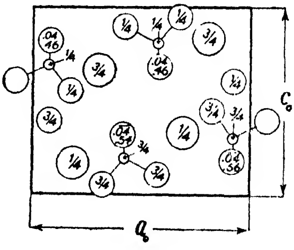


FIG. 310.—(*right*) The arrangement selected for $KClO_4$ projected upon its b-face. Atoms of the ClO_4 tetrahedra are united by light lines.

TABLE VI. PARAMETERS OF THE ATOMS IN $KMnO_4$, $KClO_4$ AND NH_4ClO_4

		$KMnO_4$			*$KClO_4$**			*NH_4ClO_4**		
Atom	*Positions*	*x*	*y*	*z*	*x*	*y*	*z*	*x*	*y*	*z*
K or NH_4	(c)	0.19	¼	0.16	0.192	¼	0.167	0.197	¼	0.172
Mn or Cl	(c)	.07	¼	.67	.075	¼	.689	.067	¼	.694
O(1)	(c)	.99	¼	.49	.175	¼	.550	.169	¼	.550
O(2)	(c)	.25	¼	.61	−.078	¼	.606	−.078	¼	.600
O(3)	(d)	.07	0.03	.80	.083	0.042	.819	.075	0.042	.819

* These values are obtained from the parameters of **1932**, 177 by adding ½ to the z coordinates of Cl, O(1) and O(2), and by changing the sign of x of O(2) and z of O(3).

the same origin, are listed in Table VI. The necessary coordinates (as stated on p. 283 of book) are:

(c) $\pm(u\frac{1}{4}v)$; $\pm(u+\frac{1}{2}, \frac{1}{4}, \frac{1}{2}-v)$
(d) $\pm(xyz)$; $\pm(x, \frac{1}{2}-y, z)$; $\pm(x+\frac{1}{2}, y, \frac{1}{2}-z)$; $\pm(x+\frac{1}{2}, \frac{1}{2}-y, \frac{1}{2}-z)$.

It is interesting that in spite of the very different positions of atoms O(1) and O(2), neither of these arrangements gives unreasonable atomic separations and each is supposed to be required by the observed data. Additional work will undoubtedly provide another demonstration of the fact that acceptable interatomic distances and qualitative agreement with a limited number of intensity estimations are insufficient to establish most structures with many parameters.

(*as*) Atomic positions have been found in two crystals isomorphous with K_2SO_4 (*m*)—$\mathbf{K_2CrO_4}$ and $\mathbf{(NH_4)_2BeF_4}$. Their parameters (Table VII) are essentially those previously chosen for the alkali sulfates. The values recorded for K_2CrO_4 in Table VII have been derived from the conclusions of **1931**, 501 by reversing the signs along c and adding one half.

TABLE VII. PARAMETERS OF THE ATOMS IN K_2CrO_4 AND $(NH_4)_2BeF_4$

	For K_2CrO_4					*For $(NH_4)_2BeF_4$*		
Atom	*No. per cell*	*x*	*y*	*z*	*Atom*	*x*	*y*	*z*
K(1)	4	$\frac{1}{4}$	0.417	0.644	$NH_4(1)$	$\frac{1}{4}$	0.393	0.675
K(2)	4	$\frac{1}{4}$	−.305	0	$NH_4(2)$	$\frac{1}{4}$	−.325	−.046
Cr	4	$\frac{1}{4}$	.417	.230	Be	$\frac{1}{4}$	.417	.263
O(1)	4	$\frac{1}{4}$	.417	.019	F(1)	$\frac{1}{4}$	.390	.051
O(2)	4	$\frac{1}{4}$	.561	.300	F(2)	$\frac{1}{4}$	.573	.300
O(3)	8	0.028	.345	.300	F(3)	0.024	.353	.350

(*at*) The unit cube of $\mathbf{K_2Mg_2(SO_4)_3}$ contains four molecules. Its space group has been found to be T^4.

(*au*) The mineral **triphylite, $\mathbf{Li(Fe,Mn)PO_4}$**, and the compound $\mathbf{Li_3PO_4}$ have orthorhombic cells similar in size and shape to the unit of chrysoberyl, $BeAl_2O_4$, (*l*). It has been inferred that their structures too are similar.

(*av*) The monoclinic unit of $\mathbf{Li_2SO_4}$ contains four molecules. An arrangement, based on spectral photographs, places all its atoms in the general positions (e) $\pm(xyz)$; $\pm(\frac{1}{2}-x, y+\frac{1}{2}, z)$ of C_{2h}^5. The chosen parameters, recorded in Table VIII, give the grouping illustrated in Figure 311.

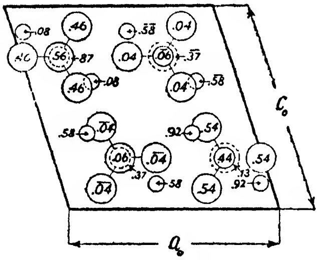
(*aw*) The monoclinic cell of $\mathbf{(NH_4)_2CrO_4}$ is bimolecular. The space group is reported to be C_s^1.

(*ax*) **Ammonium osmiamate, $\mathbf{NH_4OsNO_3}$**, like $CsReO_4$ (*am*), has a four-molecule pseudo-tetragonal orthorhombic unit suggesting the tetragonal $CaWO_4$ (*d*) arrangement. The space group assigned to NH_4OsNO_3, V^4, is different from that proposed for $CsReO_4$.

The rubidium and thallium salts, $RbOsNO_3$ and $TlOsNO_3$, are structurally isomorphous with NH_4OsNO_3. It is thought that the rubidium and osmium atoms in the general positions of V^4, xyz; $x+\frac{1}{2}, \frac{1}{2}-y, \bar{z}$; $\bar{x}, y+\frac{1}{2}, \frac{1}{2}-z$; $\frac{1}{2}-x, \bar{y}, z+\frac{1}{2}$, have as approximate parameters, for Rb: $x=0.03$, $y=\frac{1}{4}$, $z=\frac{5}{8}$; for Os: $x=0.03$, $y=\frac{1}{4}$, $z=\frac{1}{8}$.

Table VIII. Parameters of the Atoms in Li_2SO_4

Atom	*x*	*y*	*z*
Li(1)	0.205	0.582	0.375
Li(2)	.455	.582	.125
S	.319	.061	.250
O(1)	.492	−.042	.250
O(2)	.186	−.042	.099
O(3)	.280	−.042	.401
O(4)	.319	.367	.250



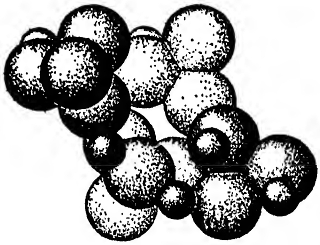


Fig. 311*a*.—(*left*) The monoclinic structure determined for Li_2SO_4 projected on its b-face. The largest circles are O, the smallest are Li atoms.

Fig. 311*b*.—(*right*) A packing drawing of *a* showing Li ions and SO_4 tetrahedra.

(*ay*) Two minerals, **adelite** and **tilasite**, each of which is essentially $CaMg(OH)AsO_4$, have units similar in shape and size though the first is orthorhombic, the latter monoclinic. Both cells contain four molecules.

(*az*) The space group of **descloizite**, $PbZn(OH)VO_4$, has been fixed as V_h^{16}; its cell includes four molecules. The following minerals are said to be isomorphous, with Cu sometimes replacing some Zn: cuprodescloizite, mottramite, psittacinite, chileite, eusynchite and dechinite.

(*ba*) The mineral **beryllonite** is orthorhombic both in its crystallography and its X-ray data. The optical anomalies it shows have, however, been considered to be sufficiently marked to prove its monoclinic symmetry. For such a crystal the 12-molecule cell of the table is without doubt too large to be the true unit.

(*bb*) The monoclinic cell of **ammonium persulfate, $(NH_4)_2S_2O_8$,** is bimolecular. From Laue and spectral photographs it has been concluded that the space group is C_{2h}^5 with all atoms in the general positions (e) $\pm(xyz)$; $\pm(x+\frac{1}{2}, \frac{1}{2}-y, z+\frac{1}{2})$[see p. 58]. The chosen atomic parameters are listed in Table IX. As can be seen from Figure 312a and b, this determination yields an S_2O_8 ion which consists of two SO_4 tetrahedra joined through an oxygen-to-oxygen bond (O-O = 1.46 A).

The cesium analogue, $Cs_2S_2O_8$, is isomorphous. Cesium parameters have been taken as x = 0.144, y = 0.125, z = 0.228; the parameters for the other atoms have the same values as in the ammonium salt.

TABLE IX. PARAMETERS OF THE ATOMS IN $(NH_4)_2S_2O_8$

Atom	*x*	*y*	*z*
NH_4	0.144	0.125	0.250
S	.136	.350	.708
O(1)	.042	.500	.611
O(2)	.028	.194	.680
O(3)	.208	.417	.930
O(4)	.292	.347	.597

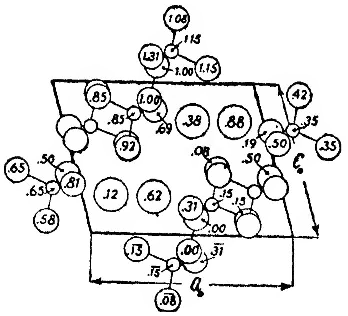


FIG. 312*a*.—(*left*) The monoclinic arrangement found for $(NH_4)_2S_2O_8$ projected on its b-face. The largest circles are NH_4 ions; the atoms of S_2O_8 ions are connected by light lines.

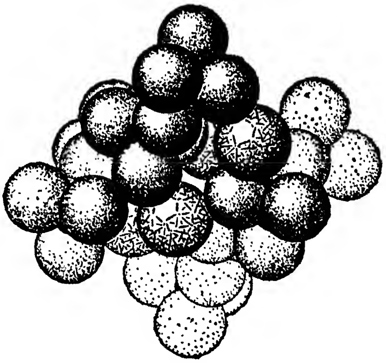


FIG. 312*b*.—(*right*) A packing drawing of *a*. The NH_4 ions are line-shaded.

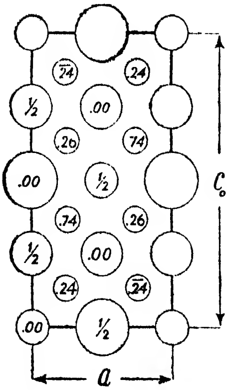
(*bc*) Four molecules are to be found in the unit prism of anhydrous **$ZnSO_4$.** Its space group has not yet been established.

(*bd*) The sulfide mineral **stannite, Cu_2FeSnS_4,** has a tetragonal two-molecule unit. Photographic data have placed its atoms in the following special positions of V_d^{11}:

Fe: (a) $000; \frac{1}{2}\frac{1}{2}\frac{1}{2}$
Cu: (d) $\frac{1}{2}0\frac{1}{4}; \frac{1}{2}0\frac{3}{4}; 0\frac{1}{2}\frac{1}{4}; 0\frac{1}{2}\frac{3}{4}$
Sn: (b) $00\frac{1}{2}; \frac{1}{2}\frac{1}{2}0$
S: (i) $uuv; u\bar{u}\bar{v}; \bar{u}\bar{u}v; \bar{u}u\bar{v}$

and four similar positions about $\frac{1}{2}\frac{1}{2}\frac{1}{2}$.

Like most other sulfides this structure for stannite (Figure 312c and d) can be considered as an assemblage of tetrahedra with sulfur at their centers. The interatomic distances that prevail are Cu-S = 2.31 A, Sn-S = 2.43 A, Fe-S = 2.36 A. Of these the iron-sulfur separation is exceptionally large.



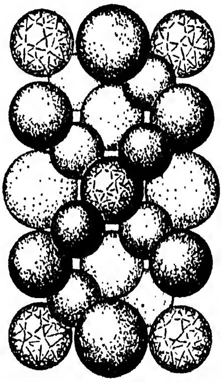


Fig. 312*c*.—(*left*) The tetragonal structure found for stannite, Cu_2FeSnS_4, projected on an a-face. Atoms of Sn, Cu, Fe and S are represented by circles of decreasing size.

Fig. 312*d*.—(*right*) A packing drawing of *c* in which atoms have their neutral radii. Atoms of Fe are line-shaded.

Chapter XVIIA. Structures of the Type $R_x(MX_6)_y$

(*j*) A number of compounds isomorphous with **$Ba_2Ni(NO_2)_6$** are reported to be cubic and to have the $(NH_4)_2PtCl_6$ structure (*a*). A more detailed study of one or more of these crystals is needed to insure that the symmetry really is cubic and to establish the positions of the nitrogen and oxygen atoms.

(*k*) Several complex nitrites isomorphous with **$Cs_3Rh(NO_2)_6$** are said to be cubic. Their atomic arrangements are considered to be like that of $(NH_4)_3FeF_6$ (*g*) with nitrogen in place of fluorine and oxygen in positions (48f) $u\bar{u}0$; etc. (1930, 352, p. 113). For several of these crystals u(N) has been chosen as 0.26, u′(O) as 0.13. Such a distribution is improbable since it would cause the oxygen atoms to be shared between neighboring nitrogen atoms instead of forming distinct NO_2 groups.

(*l*) The unit cubes of $Ca_3[Al(OH)_6]_2$ and of $Sr_3[Al(OH)_6]_2$ have been described as containing eight molecules; their space groups are given as O_h^{10}.

(*m*) The unit cubes of the **alkali fluophosphates** isomorphous with KPF_6 contain four molecules. Their space group is thought to be T^2 and it is asserted that the observed intensities conflict with the idea of PF_6 radicals. Further work is obviously needed before anything is known about the structures of these crystals.

(*n*) The bromine parameter in **K_2SeBr_6** has been determined as 0.245; in **$(NH_4)_2SeBr_6$** it lies between 0.24 and 0.25. It has been stated that for all similar compounds listed in Table I, u(Cl) is greater than 0.23 and less than 0.25.

(*o*) The compound **NaK_2AlF_6** has been given a structure which is a slight distortion of the $(NH_4)_3FeF_6$ arrangement (*g*). Aluminum atoms are at (4b) 000; etc., Na at (4c) $\frac{1}{2}\frac{1}{2}\frac{1}{2}$; etc. The potassium atoms are in (8h) with a parameter u=0.25 thus making their positions identical with (8e) $\frac{1}{4}\frac{1}{4}\frac{1}{4}$; etc. The fluorine atoms are put in general positions (d) xyz; etc. of T_h^6 (see p. 268 of book) with x=0.03, y=0.01, z=0.22. No data have been published which allow an estimate of the accuracy of this determination.

TABLE I. THE CRYSTAL STRUCTURES OF THE COMPOUNDS $R_x(MX_6)_y$

Substance, symmetry and structure type			a_o	c_o *or* α	*References*
$Ba_2Ni(NO_2)_6$	Cubic	(*j*)	10.67		**1933**, 135.
$Ba_3[Rh(NO_2)_6]_2$	Cubic or Pseudo-cubic	(*r*)	10.70		**1933**, 134.
$Ca_3[Al(OH)_6]_2$	Cubic	(*l*)	12.56		**1933**, 70.
$Cs_2AgAuCl_6$	Cubic	(*s*)	5.33		**1934**, 78.
$Cs_2Au^+Au^{+++}Cl_6$	Cubic	(*s*)	5.33		**1934**, 78.
$Cs_3Co(NO_2)_6$	Cubic	(*k*)	11.15		**1933**, 133.
$Cs_3Fe(CN)_6$		(*e*)			**1931**, 314.
$Cs_3Ir(NO_2)_6$	Cubic	(*k*)	11.17		**1933**, 132.
$CsPF_6$	Cubic	(*m*)	8.19		**1931**, 407, 408.
Cs_2PbCl_6	Cubic	$(NH_4)_2PtCl_6$ (*a*), (*n*)	10.415		**1933**, 126; **1934**, 325.
Cs_2PtCl_6	Cubic	$(NH_4)_2PtCl_6$ (*a*), (*n*)	10.185*		**1932**, 325; **1933**, 54, 126; **1934**, 325.
$Cs_3Rh(NO_2)_6$	Cubic	(*k*)	11.30		**1933**, 134.
Cs_2SeCl_6	Cubic	$(NH_4)_2PtCl_6$ (*a*), (*n*)	10.260		**1934**, 325.
Cs_2SnCl_6	Cubic	$(NH_4)_2PtCl_6$ (*a*), (*n*)	10.348		**1933**, 126; **1934**, 325.
Cs_2TeCl_6	Cubic	$(NH_4)_2PtCl_6$ (*a*), (*n*)	10.449		**1932**, 326; **1933**, 126; **1934**, 325.
Cs_2TiCl_6	Cubic	$(NH_4)_2PtCl_6$ (*a*), (*n*)	10.219		**1934**, 325.
Cs_2ZrCl_6	Cubic	$(NH_4)_2PtCl_6$ (*a*), (*n*)	10.407		**1934**, 325.
$K_2BaCo(NO_2)_6$	Cubic	(*f*)	10.45		**1931**, 111.
$K_2BaNi(NO_2)_6$	Cubic	(*f*)	10.67		**1931**, 111.
$K_2CaCo(NO_2)_6$	Cubic	(*f*)	10.17		**1931**, 111.
$K_2CaNi(NO_2)_6$	Cubic	(*f*)	10.29		**1931**, 111.
$K_3Co(NO_2)_6$	Cubic (?)	(*k*)	10.44		**1931**, 111a; **1933**, 133.
$K_3Cr(CN)_6$		(*d*)			**1931**, 314.
$K_3Fe(CN)_6$		(*d*)			**1931**, 314; **1933**, 83.
$K_3Ir(CN)_6$		(*d*)			**1931**, 314.
$K_3Ir(NO_2)_6$	Cubic	(*k*)	10.57		**1933**, 132.
$K_3Mn(CN)_6$		(*d*)			**1931**, 314.
K_2NaAlF_6	Cubic	(*o*)	8.69		**1932**, 311.
$K_4Ni(NO_2)_6$	Cubic (?)	(*p*)	10.49		**1931**, 111a.
K_2OsNCl_6†					**1933**, 483.
$K_2OsO_2Cl_4$	Tetragonal	(*q*)	6.99	8.75	**1934**, 109.
KPF_6	Cubic	(*m*)	7.76		**1931**, 407, 408.
K_2PtCl_6	Cubic	$(NH_4)_2PtCl_6$ (*a*), (*n*)	9.725		**1934**, 325.
$K_3Rh(NO_2)_6$	Cubic	(*k*)	10.63		**1933**, 134.
K_2SeBr_6	Cubic	$(NH_4)_2PtCl_6$ (*a*), (*n*)	10.363		**1933**, 200.

---

* According to **1933**, 54, $a_o = 10.120$ A.

† Journal not available.

Substance, symmetry and structure type			a_0	c_0 *or* α	*References*
K_2SnCl_6	Cubic	$(NH_4)_2PtCl_6$ (*a*), (*n*)	9.983		**1934**, 325.
$K_2SrCo(NO_2)_6$	Cubic	(*f*)	10.23		**1931**, 111.
$K_2SrNi(NO_2)_6$	Cubic	(*f*)	10.49		**1931**, 111.
K_2TeCl_6	Cubic	$(NH_4)_2PtCl_6$ (*a*), (*n*)	10.143		**1934**, 325.
$(NH_4)_3Co(NO_2)_6$	Cubic	(*k*)	10.81		**1933**, 133.
$(NH_4)_3CrF_6$	Cubic	(*g*)	9.01		**1932**, 356.
$(NH_4)_3Ir(NO_2)_6$	Cubic	(*k*)	10.73		**1933**, 132.
NH_4PF_6	Cubic	(*m*)	7.92		**1931**, 407, 408.
$(NH_4)_2PbCl_6$	Cubic	$(NH_4)_2PtCl_6$ (*a*), (*n*)	10.135		**1934**, 325.
$(NH_4)_2PtCl_6$	Cubic	$(NH_4)_2PtCl_6$ (*a*), (*n*)	9.834		**1934**, 325.
$(NH_4)_3Rh(NO_2)_6$	Cubic	(*k*)	10.91		**1933**, 134.
$(NH_4)_2SeBr_6$	Cubic	$(NH_4)_2PtCl_6$ (*a*), (*n*)	10.46		**1932**, 425.
$(NH_4)_2SeCl_6$	Cubic	$(NH_4)_2PtCl_6$ (*a*), (*n*)	9.935		**1934**, 325.
$(NH_4)_2SiF_6$	Hexagonal	(*t*)	5.76	4.77	**1934**, 87.
$(NH_4)_2SnCl_6$	Cubic	$(NH_4)_2PtCl_6$ (*a*), (*n*)	10.038		**1934**, 325.
$(NH_4)_2TeCl_6$	Cubic	$(NH_4)_2PtCl_6$ (*a*), (*n*)	10.178		**1934**, 325.
$(NH_4)_3VF_6$	Cubic	(*g*)	9.04		**1932**, 355.
Na_3AlF_6		(*h*)			**1932**, 311.
$Pb_2Ni(NO_2)_6$	Cubic	(*j*)	10.55		**1933**, 135.
$Pb_3[Rh(NO_2)_6]_2$	Cubic or Pseudo-cubic	(*r*)	10.53		**1933**, 134.
$Rb_3Co(NO_2)_6$	Cubic	(*k*)	10.73		**1933**, 133.
$Rb_3Fe(CN)_6$	Monoclinic	$K_3Fe(CN)_6$ (*d*)	13.74 $b_0=10.66$, $\beta=90°3'$	8.63	**1933**, 83.
$Rb_3Ir(NO_2)_6$	Cubic	(*k*)	10.77		**1933**, 132.
Rb_2PbCl_6	Cubic	$(NH_4)_2PtCl_6$ (*a*), (*n*)	10.198		**1933**, 126; **1934**, 325.
Rb_2PtCl_6	Cubic	$(NH_4)_2PtCl_6$ (*a*), (*n*)	9.882		**1932**, 325; **1933**, 54, 126; **1934**, 325.
$Rb_3Rh(NO_2)_6$	Cubic	(*k*)	10.83		**1933**, 134.
Rb_2SeCl_6	Cubic	$(NH_4)_2PtCl_6$ (*a*), (*n*)	9.978		**1934**, 325.
Rb_2SnCl_6	Cubic	$(NH_4)_2PtCl_6$ (*a*), (*n*)	10.100		**1933**, 126; **1934**, 325.
Rb_2TeCl_6	Cubic	$(NH_4)_2PtCl_6$ (*a*), (*n*)	10.233		**1933**, 126; **1934**, 325.
Rb_2TiCl_6	Cubic	$(NH_4)_2PtCl_6$ (*a*), (*n*)	9.922		**1934**, 325.
Rb_2ZrCl_6	Cubic	$(NH_4)_2PtCl_6$ (*a*), (*n*)	10.178		**1934**, 325.
$Sr_3[Al(OH)_6]_2$	Cubic	(*l*)	13.02		**1933**, 70.
$Sr_2Ni(NO_2)_6$	Cubic	(*j*)	10.54		**1933**, 135.
$Tl_3Co(NO_2)_6$	Cubic	(*k*)	10.72		**1933**, 133.

Substance, symmetry and structure type			a_0	c_0 or α	References
$Tl_3Ir(NO_2)_6$	Cubic	(k)	10.73		1933, 132.
Tl_2PtCl_6	Cubic	$(NH_4)_2PtCl_6$ (a), (n)	9.755		1934, 325.
$Tl_3Rh(NO_2)_6$	Cubic	(k)	10.91		1933, 134.
Tl_2SiF_6	Cubic	$(NH_4)_2PtCl_6$ (a)	8.60		1933, 460.
Tl_2SnCl_6	Cubic	$(NH_4)_2PtCl_6$ (a), (n)	9.970		1934, 325.
Tl_2TeCl_6	Cubic	$(NH_4)_2PtCl_6$ (a), (n)	10.107		1934, 325.

(*p*) The compound **$K_4Ni(NO_2)_6$**, which probably has less than cubic symmetry, has been given a cubic or pseudo-cubic unit containing four molecules.

(*q*) The tetragonal unit of **potassium osmyl chloride, $K_2OsO_2Cl_4$**, is bimolecular. Its atoms, with an arrangement which is a slight distortion of the familiar $(NH_4)_2PtCl_6$ grouping (*a*), are in the following special positions of D_{4h}^{17}:

Os: (a) $000;\ \frac{1}{2}\frac{1}{2}\frac{1}{2}$ K: (d) $0\frac{1}{2}\frac{1}{4};\ \frac{1}{2}0\frac{1}{4};\ 0\frac{1}{2}\frac{3}{4};\ \frac{1}{2}0\frac{3}{4}$
O: (e) $00u';\ 00\bar{u}';\ \frac{1}{2}, \frac{1}{2}, \frac{1}{2}-u';\ \frac{1}{2}, \frac{1}{2}, u'+\frac{1}{2}$ with $u'=0.21$
Cl: (h) $uu0;\ u\bar{u}0;\ u+\frac{1}{2}, \frac{1}{2}-u, \frac{1}{2};\ u+\frac{1}{2}, u+\frac{1}{2}, \frac{1}{2};\ \bar{u}\bar{u}0;\ \bar{u}u0;$
$\frac{1}{2}-u, u+\frac{1}{2}, \frac{1}{2};\ \frac{1}{2}-u, \frac{1}{2}-u, \frac{1}{2}$ with $u=0.230$.

(*r*) Unit cubes or pseudo-cubes of $Ba_3[Rh(NO_2)_6]_2$ and $Pb_3[Rh(NO_2)_6]_2$ are supposed to contain two molecules.

(*s*) Powder patterns obtained from the triple halides **$Cs_2AgAuCl_6$** and **$Cs_2Au^+Au^{+++}Cl_6$** have only the lines required by a perowskite, $CaTiO_3$ [XV, (*d*)], arrangement. Such a unit would contain only half a molecule; hence it is suggested that the atoms have as coordinates: Cs: 000, Cl: $0\frac{1}{2}\frac{1}{2};\ \frac{1}{2}0\frac{1}{2};\ \frac{1}{2}\frac{1}{2}0$, Ag (or Au^+) and Au^{+++} at $\frac{1}{2}\frac{1}{2}\frac{1}{2}$ in different cells. Though the structure probably approaches such a simple atomic distribution, the true unit undoubtedly is a larger one.

(*t*) The unit prism established for the hexagonal modification of **$(NH_4)_2SiF_6$** is unimolecular. A structure has been proposed which places atoms in the following special positions of D_{3d}^3:

NH_4: (d) $\frac{1}{3}\frac{2}{3}u;\ \frac{2}{3}\frac{1}{3}\bar{u}$ with $u=\frac{3}{4}$ Si: (a) 000
F: (i) $\pm(u\bar{u}v);\ \pm(2\bar{u}, \bar{u}, v);\ \pm(u, 2u, v)$ with $u=0.136$, $v=$ ca $\frac{1}{5}$.

Practically no data have been published in support of this arrangement.

Chapter XVIIIA. Structures of Hydrates and Ammoniates and of Miscellaneous Inorganic Compounds

Hydrates and Ammoniates

The hydrates thus far analyzed by X-ray methods fall into three types. Most of them, and all of the ammoniates, are coordination compounds in which the H_2O or NH_3 molecules are closely bound to the metal atoms present. In a few of the crystals described below water molecules are not thus associated with cations but occupy holes in the lattice. Such a water molecule is present in $Pd(NH_3)_4Cl_2 \cdot H_2O$ (*ba*); the fifth H_2O in $CuSO_4 \cdot 5H_2O$ is similarly held. Though these H_2O molecules cannot be driven off without destroying the rest of the atomic arrangement, in many other ways their bonding resembles that seen in the zeolites. To the third type belong those compounds, like $Al_2O_3 \cdot H_2O$ or $Al_2O_3 \cdot 3H_2O$, with water so firmly held that it may be present as hydroxyl groups. Many minerals contain such "water of constitution."

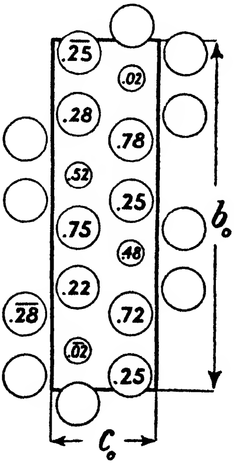


FIG. 313*a*.—(*left*) A portion of the diaspore, $Al_2O_3 \cdot H_2O$, structure projected on an a-face. Small circles are Al atoms. Water molecules, as such, do not exist in this grouping.

FIG. 313*b*.—(*right*) A packing drawing of *a*.

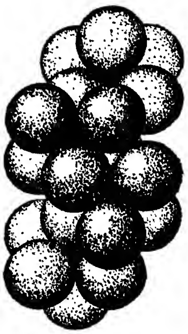


TABLE I. THE CRYSTAL STRUCTURES OF HYDRATES AND AMMONIATES

Substance, symmetry and structure type			a_o	c_o *or* α	*References*
$Al_2O_3 \cdot H_2O$ (Diaspore)	Orthorhombic	$Al_2O_3 \cdot H_2O$ (*a*), (*ae*)	4.43	2.80 $b_o=9.36$	**1932**, 121; **1933**, 462.
$CaCrO_4 \cdot H_2O$	Orthorhombic	(*af*)	7.99	8.11 $b_o=12.77$	**1932**, 106.
$2(CaSO_4) \cdot$ ca H_2O	Hexagonal	(*ag*)	6.76	6.24	**1934**, 46.
$Fe_2O_3 \cdot H_2O$ (Goethite)	Orthorhombic	$Al_2O_3 \cdot H_2O$ (*a*), (*ae*)	4.64	3.03 $b_o=10.0$	**1931**, 132; **1932**, 168.
$Fe_2O_3 \cdot H_2O$ (Lepidocrocite)	Orthorhombic	(*ae*)	3.87	3.06 $b_o=12.4$	**1931**, 132.
$3(KPbCl_3) \cdot H_2O$	Triclinic		14.35	14.50* $b_o=9.05$	**1934**, 172.
$Li_2SO_4 \cdot H_2O$	Monoclinic	(*br*)	5.43	8.14 $b_o=4.83$, $\beta=107°35'$	**1934**, 361.
$Mn_2O_3 \cdot H_2O$ (Manganite)	Orthorhombic	(*ah*)	4.41	2.83 $b_o=5.19$	**1931**, 112.
$Na_2CO_3 \cdot H_2O$	Orthorhombic	(*bs*)	10.72	5.24 $b_o=6.44$	**1934**, 321.
$Rb_2(CrF_5 \cdot H_2O)$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	8.38		**1932**, 356.
$Sb_2O_4 \cdot H_2O$ (Stibiconite)	Cubic	(*ai*)	10.24		**1933**, 316.
$Tl_2(VF_5 \cdot H_2O)$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	8.45		**1932**, 355.
$AgNO_3 \cdot 2NH_3$	Orthorhombic	(*bt*)	8.00	6.29 $b_o=10.58$	**1934**, 58.
$CaCrO_4 \cdot 2H_2O$	Orthorhombic	(*aj*)	16.02	5.60 $b_o=11.39$	**1932**, 106.
$CaHPO_4 \cdot 2H_2O$ (Brushite)	Monoclinic	(*ak*)	10.47	6.28 $b_o=15.15$, $\beta=98°58'$	**1931**, 149.
$CaSO_4 \cdot 2H_2O$ (Gypsum)	Monoclinic	(*d*), (*ak*)			**1931**, 149; **1934**, 347a.
$Cd(ClO_2)_2 \cdot 2H_2O$	Monoclinic	(*al*)	8.86	9.76 $b_o=7.12$, $\beta=90°18'$	**1931**, 282.
$K_2CuCl_4 \cdot 2H_2O$	Tetragonal	(*e*), (*am*)			**1934**, 48.
$(NH_4)_2CuBr_4 \cdot 2H_2O$	Tetragonal	$(NH_4)_2CuCl_4 \cdot 2H_2O$ (*e*), (*am*)	7.83	8.14	**1933**, 370.
$(NH_4)_2CuCl_4 \cdot 2H_2O$	Tetragonal	(*e*), (*am*)			**1934**, 48.
$NaBr \cdot 2H_2O$	Monoclinic	(*an*)	6.59	6.51 $b_o=10.20$, $\beta=112°30'$	**1932**, 482.
$NaI \cdot 2H_2O$	Triclinic	(*ao*)	6.85	7.16 $b_o=5.76$, $\alpha=98°$, $\beta=119°$, $\gamma=68\frac{1}{2}°$	**1932**, 482.
α-$Pt(NH_3)_2Cl_4$	Tetragonal	(*ap*)	5.72	10.37	**1933**, 109.
β-$Pt(NH_3)_2Cl_4$	Orthorhombic	(*ap*)	10.0	6.0 $b_o=11.2$	**1933**, 109.

---

* For $3(KPbCl_3) \cdot H_2O$, $\alpha=\gamma=$ ca 90°, $\beta=113°$.

Substance, symmetry and structure type			a_0	c_0 *or* α	*References*
$Zn(ClO_2)_2 \cdot 2H_2O$	Monoclinic	(*al*)	8.67	9.38	**1931**, 282.
			$b_0=6.88$, $\beta=90°20'$		
$Al_2O_3 \cdot 3H_2O$ (Gibbsite)	Monoclinic	(*aq*)	8.6236	9.699	**1934**, 170.
			$b_0=5.0602$, $\beta=85°26'$		
$Ba(ClO_4)_2 \cdot 3H_2O$	Hexagonal	(*bq*)	7.28	9.64	**1934**, 290.
$LiClO_4 \cdot 3H_2O$	Hexagonal	(*bp*)	7.71	5.42	**1934**, 290.
$LiI \cdot 3H_2O$	Hexagonal	(*f*), (*bp*)			**1934**, 290.
$Ag_2SO_4 \cdot 4NH_3$	Tetragonal	(*ar*)	8.43	6.35	**1934**, 59.
$BaNi(CN)_4 \cdot 4H_2O$	Monoclinic	(*as*)	11.71	6.63	**1934**, 32, 33.
			$b_0=13.48$, $\beta=104°50'$		
$BaPt(CN)_4 \cdot 4H_2O$	Monoclinic	(*as*)	11.89	6.54	**1933**, 72.
			$b_0=14.08$, $\beta=103°42'$		
$BeSO_4 \cdot 4H_2O$	Tetragonal	(*h*), (*at*)	8.02	10.75	**1931**, 401; **1932**, 31.
$[Co\substack{CO_3\\(NH_3)_4}]ClO_4$	Ortho-rhombic	(*au*)	18.05	6.95	**1933**, 455.
			$b_0=8.10$		
$1, 6[Co\substack{(NO_2)_2\\(NH_3)_4}]Cl$	Ortho-rhombic	(*av*)	14.36	13.98	**1933**, 456.
			$b_0=17.97$		
$Na_2B_4O_7 \cdot 4H_2O$ (Kernite)	Monoclinic	(*aw*)	15.65	7.01	**1932**, 156, 157.
			$b_0=9.07$, $\beta=108°52'$		
$[Pt(NH_3)_4]PtCl_4$ (Magnus' Green Salt)	Tetragonal	(*ax*)	6.297	6.42‡	**1931**, 193; **1932**, 119.
$[Pt(NH_3)_4]PtCl_4$ (Magnus' Red Salt)		(*ax*)			**1931**, 193; **1932**, 119.
$Zn(ClO_4)_2 \cdot 4NH_3$	Cubic	(*ay*)	10.250		**1933**, 53.
$CuSO_4 \cdot 5H_2O$	Triclinic	(*i*), (*az*)	5.12	5.97	**1933**, 32; **1934**, 15, 15a.
		$b_0=10.7$, $\alpha=82°16'$, $\beta=107°26'$, $\gamma=102°40'$			
$H_3PW_{12}O_{40} \cdot 5H_2O$	Cubic	(*bk*)	12.14		**1934**, 131.
$Pd(NH_3)_4Cl_2 \cdot H_2O$	Tetragonal	(*ba*)	10.302	4.34	**1933**, 109; **1934**, 71.
$Pt(NH_3)_4Cl_2 \cdot H_2O$	Tetragonal	(*ba*)	10.44	4.21	**1932**, 114; **1933**, 109.
$AlCl_3 \cdot 6H_2O$	Hexagonal	(*bb*)	7.85	97°±20′	**1934**, 3.
$BaI_2 \cdot 6H_2O$	Hexagonal	$SrCl_2 \cdot 6H_2O$ (*p*)	8.90	4.60	**1931**, 185.
$CaBr_2 \cdot 6H_2O$	Hexagonal	$SrCl_2 \cdot 6H_2O$ (*p*)	7.97	3.97	**1931**, 184.
$CaBr_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	10.706		**1933**, 56.
$CaCl_2 \cdot 6H_2O$	Hexagonal	$SrCl_2 \cdot 6H_2O$ (*p*)	7.86	3.905	**1931**, 184.
$CaI_2 \cdot 6H_2O$	Hexagonal	$SrCl_2 \cdot 6H_2O$ (*p*)	8.4	4.25	**1931**, 185.
$CaI_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	11.24		**1933**, 56.
$Cd(BF_4)_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	11.380		**1933**, 54.
$CdBr_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	11.540		**1933**, 56.

---

‡ In **1931**, 193, $c_0=5.15$ A.

Substance, symmetry and structure type			a_0	c_0 *or* α	*References*
$Cd(ClO_4)_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	11.588		1933, 53.
$CdI_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	11.046		1933, 53.
$Cd(SO_3F)_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	11.619		1933, 54.
$CdSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$	Monoclinic	(*n*)	9.35 $b_0=12.705$, $\beta=106°41'$	6.27	1931, 211.
$[Co \cdot 6NH_3](BF_4)_2$	Cubic	(*m*)	11.265		1932, 195; 1933, 54.
$[Co \cdot 6NH_3](BF_4)_3$	Cubic	$(NH_4)_3FeF_6$ (*l*)	11.211		1933, 53.
$[Co \cdot 6NH_3]Br_2$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	10.389		1933, 55.
$[Co \cdot 6NH_3]Cl_2$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	10.10		1933, 55.
$[Co \cdot 6NH_3](ClO_4)_2$	Cubic	(*m*)	11.449		1932, 195.
$[Co \cdot 6NH_3](ClO_4)_3$	Cubic	(*l*)	11.384		1932, 195.
$[Co \cdot 6NH_3]I_2$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	10.914		1933, 55.
$[Co \cdot 6(NH_2 \cdot CH_3)]I_2$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	12.05		1933, 55.
$[Co \cdot 6NH_3](PF_6)_2$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	11.942		1933, 53.
$[Co \cdot 6NH_3](PF_6)_3$	Cubic	$(NH_4)_3FeF_6$ (*l*)	11.670		1933, 53.
$[Co \cdot 6NH_3](SO_3F)_2$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	11.490		1933, 54.
$CoSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$	Monoclinic	(*n*)	9.23 $b_0=12.49$, $\beta=106°56'$	6.23	1931. 150.
$CrCl_3 \cdot 6H_2O$	Hexagonal	(*bb*)	7.95	97°±20′	1934, 3.
$Fe(BF_4)_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	11.340		1933, 54.
$FeBr_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	10.468		1933, 53.
$FeCl_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	10.148		1933, 53.
$Fe(ClO_4)_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	11.517		1933, 53.
$FeI_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	10.965		1933, 53.
$Fe(SO_3F)_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	11.544		1933, 54.
$FeSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$	Monoclinic	(*n*), (*bc*)	9.28 $b_0=12.57$, $\beta=106°50'$	6.22	1931, 211.
$Mg(BF_4)_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	11.337		1933, 54.

Substance, symmetry and structure type			a_0	c_0 *or* α	*References*
$MgBr_2 \cdot 6H_2O$	Monoclinic	(*bd*)	10.25	6.30 $b_0=7.40$, $\beta=93°30'$	**1934**, 4.
$MgBr_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	10.468		**1933**, 53.
$MgCl_2 \cdot 6H_2O$	Monoclinic	(*bd*)	9.90	6.10 $b_0=7.15$, $\beta=94° \pm 20'$	**1934**, 4.
$MgCl_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	10.158		**1933**, 53.
$Mg(ClO_4)_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	11.531		**1933**, 53.
$MgI_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	10.978		**1933**, 53.
$MgSO_4 \cdot K_2SO_4 \cdot 6H_2O$	Monoclinic	(*n*)	9.04	6.095 $b_0=12.24$, $\beta=104°48'$	**1931**, 211.
$MgNH_4AsO_4 \cdot 6H_2O$	Orthorhombic	(*bo*)	7.00	11.14 $b_0=6.14$	**1933**, 397.
$MgSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$	Monoclinic	(*n*), (*bc*)	9.28	6.20 $b_0=12.57$, $\beta=107°6'$	**1931**, 211; **1932**, 220.
$MgSeO_4 \cdot (NH_4)_2SeO_4 \cdot 6H_2O$	Monoclinic	(*n*)	9.42	6.30 $b_0=12.72$, $\beta=106°27'$	**1931**, 211.
$MgSO_4 \cdot Tl_2SO_4 \cdot 6H_2O$	Monoclinic	(*n*)	9.22	6.185 $b_0=12.42$, $\beta=106°30'$	**1931**, 211.
$Mn(BF_4)_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	11.374		**1933**, 54.
$MnBr_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	10.519		**1933**, 53.
$MnCl_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	10.198		**1933**, 53.
$Mn(ClO_4)_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	11.578		**1933**, 53.
$MnI_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	11.037		**1933**, 53.
$Mn(SO_3F)_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	11.593		**1933**, 54.
$Ni(BF_4)_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	11.219		**1932**, 195; **1933**, 54.
$NiBr_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	10.34		**1933**, 55.
$NiCl_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	10.064		**1933**, 55.
$Ni(ClO_4)_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	11.410		**1932**, 195.
$NiI_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	10.875		**1933**, 55.
$NiI_2 \cdot 6(NH_2CH_3)$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	12.027		**1933**, 55.
$Ni(PF_6)_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	11.912		**1933**, 53.
$Ni(SO_3F)_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	11.445		**1932**, 195; **1933**, 54.

Substance, symmetry and structure type			a_0	c_0 *or* α	*References*
$NiSO_4 \cdot 6H_2O$	Tetragonal	(*be*)	6.80	18.3	**1932**, 32; **1933**, 102.
$SrBr_2 \cdot 6H_2O$	Hexagonal	$SrCl_2 \cdot 6H_2O$ (*p*)	8.212	4.146	**1931**, 183.
$SrCl_2 \cdot 6H_2O$	Hexagonal	$SrCl_2 \cdot 6H_2O$ (*p*), (*bf*)	7.906	4.07	**1931**, 185.
$SrI_2 \cdot 6H_2O$	Hexagonal	$SrCl_2 \cdot 6H_2O$ (*p*)	8.51	4.29	**1931**, 184.
$ZnBr_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	10.46		**1933**, 56.
$ZnI_2 \cdot 6NH_3$	Cubic	$(NH_4)_2PtCl_6$ (*m*)	10.964		**1933**, 53.
$ZnSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$	Monoclinic	(*n*)	9.205	6.225	**1931**, 211.
			$b_0=12.475$,	$\beta=106°52'$	
$[Co{}^{CO_3}_{(NH_3)_4}]_2SO_4 \cdot 3H_2O$	Monoclinic	(*bn*)	11.80	7.42	**1933**, 454.
			$b_0=10.60$,	$\beta=98°39'$	
$MgPt(CN)_4 \cdot 7H_2O$	Tetragonal	(*t*), (*bg*)	14.6	6.26	**1932**, 60.
$MgSO_4 \cdot 7H_2O$	Ortho-rhombic				**1930**, 378; **1932**, 19.
$3CdSO_4 \cdot 8H_2O$	Monoclinic	(*bh*)	14.65	16.35	**1932**, 138.
			$b_0=11.84$,	$\beta=34°48'$	
$SrO_2 \cdot 8H_2O$	Tetragonal	(*v*), (*bi*)			**1932**, 322.
$Na_3SbS_4 \cdot 9H_2O$	Cubic*				**1933**, 483.
$4(PO_4)Al \cdot 2Al(OH)_3 \cdot 9H_2O$ (Wavellite)	Orthorhombic	(*bl*)	7.27	10.80	**1933**, 225.
			$b_0=14.41$		
$Zn_{14}(AsO_4)_9OH \cdot 12H_2O$ (Legrandite)	Monoclinic	(*bm*)	12.70	10.18	**1932**, 130.
			$b_0=7.90$,	$\beta=75°35'$	
$2Na_3PO_4 \cdot NaF \cdot 19H_2O$	Cubic	(*bj*)	27.86		**1933**, 322.
$GdPMo_{12}O_{40} \cdot 30H_2O$	Cubic	(*bk*)	23.1		**1933**, 198.
$H_3PMo_{12}O_{40} \cdot 30H_2O$	Cubic	(*bk*)	23.281		**1933**, 198, 248, 249.
$NdPMo_{12}O_{40} \cdot 30H_2O$	Cubic	(*bk*)	23.10		**1933**, 198.
$SaPMo_{12}O_{40} \cdot 30H_2O$	Cubic	(*bk*)	23.1		**1933**, 198.
$Be_2SiW_{12}O_{40} \cdot 31H_2O$	Cubic	(*bk*)	23.3		**1933**, 198.
$Mg_2SiMo_{12}O_{40} \cdot 31H_2O$	Cubic	(*bk*)	23.04		**1933**, 198.
$Ni_2SiMo_{12}O_{40} \cdot 31H_2O$	Cubic	(*bk*)	23.0		**1933**, 198.

* The journal describing this work was not available.

(*ae*) The orthorhombic units of **diaspore, $Al_2O_3 \cdot H_2O$** or $H_2Al_2O_4$, and of goethite, $Fe_2O_3 \cdot H_2O$, are bimolecular. Studied independently, they have been given identical arrangements. All atoms are in special positions (c) of V_h^{16}: $uv\frac{1}{4}$; $\bar{u}\bar{v}\frac{3}{4}$; $u+\frac{1}{2}, \frac{1}{2}-v, \frac{3}{4}$; $\frac{1}{2}-u, v+\frac{1}{2}, \frac{1}{4}$ with the values of u and v listed in Table II. Except for c_o which is half as long, the units of these oxides and of chrysoberyl, $BeAl_2O_4$, are similar in size and shape. As is readily seen by comparing Figure 313 with Figure 219 (book, p. 293) the two groupings are similar, both being packings of oxygen atoms with the small metal atoms lying in interstices.

The other monohydrate of Fe_2O_3, lepidocrocite, also has a bimolecular orthorhombic unit but its space group is V_h^1. It is said that lepidocrocite, unlike goethite, gives magnetic Fe_2O_3 on dehydration.

(*af*) The unit cell of **$CaCrO_4 \cdot H_2O$** contains eight molecules. Its probable space group is V_h^{15}.

TABLE II. PARAMETERS OF THE ATOMS IN DIASPORE AND GOETHITE

Atom	*For $Al_2O_3 \cdot H_2O$*		*For $Fe_2O_3 \cdot H_2O$*	
	u	*v*	*u*	*v*
Al or Fe	−0.02	0.11	−0.05	0.103
O(1)	.75	−.04	.75	−.04
O(2)	.22	.29	.25	.29

(*ag*) Recent work on **plaster of Paris** revives the question of whether a hemihydrate, $CaSO_4 \cdot \frac{1}{2}H_2O$, or anhydrous $CaSO_4$ provides the proper formula. It has been shown that the water remaining in burnt plaster can be nearly all removed without destroying the crystal form and without altering the diffraction pattern. From this it has been concluded that the water is present in a zeolitic condition—within holes existing in the crystalline structure. Assuming that plaster of Paris is built only of $CaSO_4$ molecules, three of them are to be found within the prism of Table I.

(*ah*) The unit cell selected for **manganite, $Mn_2O_3 \cdot H_2O$,** contains one molecule. Except for the fact that the length of the b-axis is halved, this cell is practically the same in size and shape as those of diaspore and goethite.

(*ai*) **Stibiconite, $Sb_2O_4 \cdot H_2O$,** gives a powder pattern identical with that of the anhydrous tetroxide Sb_2O_4. It is therefore not surprising that no change of pattern occurs on dehydration.

(*aj*) The unit prism of **$CaCrO_4 \cdot 2H_2O$** contains eight molecules; its space group is described as V_h^{11}.

(*ak*) **Gypsum, $CaSO_4 \cdot 2H_2O$,** and brushite, $CaHPO_4 \cdot 2H_2O$, are said to have indistinguishable X-ray patterns and hence to possess unit cells of the same size and shape. It is reported that ardealite is a 1:1 double salt of these compounds with practically the same cell.

In a very recent study it is concluded that the correct space group of gypsum is C_{2h}^6 and not C_{2h}^3 upon which the structure described in (*d*) (book, p. 314) was based.

(*al*) Four molecules are found within the monoclinic units assigned to $Cd(ClO_2)_2 \cdot 2H_2O$ and $Zn(ClO_2)_2 \cdot 2H_2O$.

(*am*) Previous studies of crystals isomorphous with $\mathbf{(NH_4)_2CuCl_4 \cdot 2H_2O}$ gave two different atomic arrangements. A reinvestigation, based on quantitative intensity data and Fourier plots of electron distributions, leads to a structure that differs from the first one described under (*e*) (book, p. 314) only in making equal the parameters u and v for the chlorine atoms in (f) and (g) [$u=v=0.220$] and in reducing the water parameters in (e) to $w=0.25$. This arrangement for $K_2CuCl_4 \cdot 2H_2O$ gives definitely better agreement with quantitative data than does the second one having chlorine atoms in (j). It is interesting that no choice between these arrangements could be made from the $(NH_4)_2CuCl_4 \cdot 2H_2O$ reflections.

(*an*) The monoclinic unit found for $\mathbf{NaBr \cdot 2H_2O}$ contains four molecules; its space group is C_{2h}^5.

(*ao*) The compound $\mathbf{NaI \cdot 2H_2O}$ is described as triclinic with a two-molecule unit and with C_i^1 as space group.

(*ap*) The **α-diamminoplatinic chloride** is reported to be tetragonal with a two-molecule unit; its space group has been given as D_{4h}^{14}.

The β-form, of a lower symmetry, is said to have a four-molecule orthorhombic unit.

(*aq*) Making use of photographic data and some spectrometric measurements a pronouncedly layer-like structure has been assigned to **gibbsite** (hydrargillite), $\mathbf{Al_2O_3 \cdot 3H_2O}$. Atoms of the 8 $Al(OH)_3$ molecules within the large monoclinic unit that has been used are in general positions of C_{2h}^5: (e) $\pm(xyz)$; $\pm(\frac{1}{2}-x, y+\frac{1}{2}, \frac{1}{2}-z)$. The chosen atomic parameters are stated in Table III.

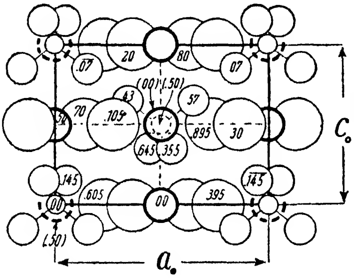
TABLE III. PARAMETERS OF THE ATOMS IN GIBBSITE, $Al_2O_3 \cdot 3H_2O$

Atom	*x*	*y*	*z*
Al(1)	0.177	0.520	−0.005
Al(2)	.333	.020	−.005
O(1)	.182	.202	−.110
O(2)	.682	.672	−.110
O(3)	.515	.132	−.110
O(4)	−.015	.632	−.110
O(5)	.298	.702	−.100
O(6)	.838	.172	−.100

(*ar*) The tetragonal unit of $\mathbf{Ag_2SO_4 \cdot 4NH_3}$ contains two molecules. Its atoms are in the following special and general positions of V_d^4:

S: (a) $000; \frac{1}{2}\frac{1}{2}\frac{1}{2}$ Ag: (d) $0\frac{1}{2}u; \frac{1}{2}0\bar{u}; \frac{1}{2}, 0, \frac{1}{2}-u; 0, \frac{1}{2}, u+\frac{1}{2}$ with $u=0.50$
O: (e) $xyz; y\bar{x}\bar{z}; \bar{x}\bar{y}z; \bar{y}x\bar{z}; \frac{1}{2}-x, y+\frac{1}{2}, \frac{1}{2}-z; \frac{1}{2}-y, \frac{1}{2}-x, z+\frac{1}{2}; x+\frac{1}{2}, \frac{1}{2}-y, \frac{1}{2}-z;$
$y+\frac{1}{2}, x+\frac{1}{2}, z+\frac{1}{2}$ with $x=0.14$, $y=0.07$, $z=0.15$
NH_4: (e) $x'y'z'$; etc. with $x'=0.10$, $y'=0.30$, $z'=0.50$.

As Figure 314 shows, this arrangement is a packing of SO_4 tetrahedra and linear NH_3-Ag-NH_3 groups.



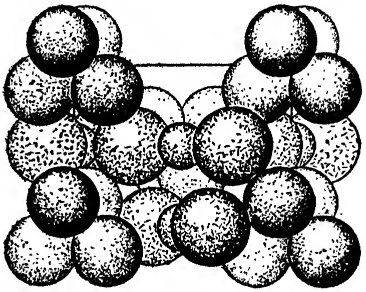


FIG. 314a.—(*left*) The structure of $Ag_2SO_4 \cdot 4NH_3$ projected on one of the a-faces of its tetragonal unit. The largest circles are NH_3 groups, the smallest are S atoms; Ag atoms are shown as thick rings.

FIG. 314b.—(*right*) A packing drawing of *a*. The small Ag atoms and the large NH_3 groups are line-shaded.

(*as*) The monoclinic units assigned to **$BaNi(CN)_4 \cdot 4H_2O$** and to the isomorphous **$BaPt(CN)_4 \cdot 4H_2O$** contain four molecules. The space group is given as C_{2h}^6 with Pt (or Ni) atoms at $000; 00\frac{1}{2}; \frac{1}{2}\frac{1}{2}0; \frac{1}{2}\frac{1}{2}\frac{1}{2}$ and Ba atoms at $0\frac{3}{8}\frac{1}{4}; 0\frac{5}{8}\frac{3}{4}; \frac{1}{2}\frac{1}{8}\frac{1}{4}; \frac{1}{2}\frac{7}{8}\frac{3}{4}$. Other atomic positions have not been fixed.

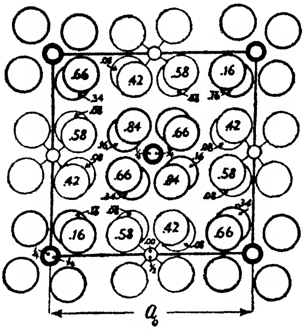
(*at*) Two determinations of the structure of **$BeSO_4 \cdot 4H_2O$** have been made from photographic data. The first (**1931**, 401), based on D_{4h}^{18}, is undoubtedly wrong. The other places atoms in the following positions of V_d^{10} (written not as the face-centered grouping of **1930**, 352, p. 77 but in terms of a diagonal body-centered unit):

S: (c) $\frac{1}{2}00; 0\frac{1}{2}0; \frac{1}{2}0\frac{1}{2}; 0\frac{1}{2}\frac{1}{2}$ Be: (b) $00\frac{1}{4}; 00\frac{3}{4}; \frac{1}{2}\frac{1}{2}\frac{1}{4}; \frac{1}{2}\frac{1}{2}\frac{3}{4}$
O: (i) $xyz; yx\bar{z}; \bar{x}\bar{y}z; \bar{y}\bar{x}\bar{z}; x+\frac{1}{2}, \frac{1}{2}-y, z; y+\frac{1}{2}, \frac{1}{2}-x, \bar{z};$
$\frac{1}{2}-y, x+\frac{1}{2}, \bar{z}; \frac{1}{2}-x, y+\frac{1}{2}, z$ and 8 similar points about $\frac{1}{2}\frac{1}{2}\frac{1}{2}$.

For the sulfate oxygen atoms $x=0.40$, $y=0.13$, $z=0.08$. The water molecules, likewise in (i), are given the parameters $x'=0.10$, $y'=0.14$, $z'=0.16$.

In this arrangement the beryllium atoms, which of course cannot be located with certainty by the X-ray data, have been placed at the centers of the groups of water molecules. The structure as a whole thus is a packing together of SO_4 and $Be(H_2O)_4$ tetrahedra (Figure 315).

(*au*) The orthorhombic cell which has been given to $[Co_{(NH_3)_4}^{CO_3}]ClO_4$ contains four molecules. Its space group is said to be C_{2v}^7.



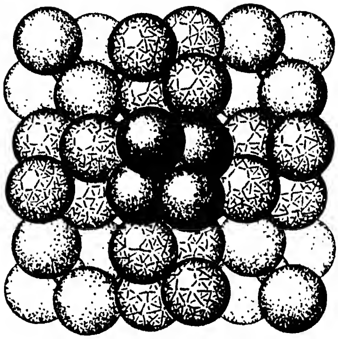


FIG. 315a.—(*left*) The atomic arrangement in tetragonal $BeSO_4 \cdot 4H_2O$ projected on its c-face. Be atoms are shown as thick rings, S atoms as the smallest circles. The H_2O molecules are thickened large circles.

FIG. 315b.—(*right*) A packing drawing of *a*. Oxygens of the SO_4 tetrahedra are line-shaded; Be atoms show within their water tetrahedra.

(*av*) The orthorhombic unit of $1,6[\mathrm{Co}^{(\mathrm{NO}_2)_2}_{(\mathrm{NH}_3)_4}]\mathrm{Cl}$ is reported to contain 16 molecules.

(*aw*) The unit found for $\mathbf{Na_2B_4O_7 \cdot 4H_2O}$ possesses four molecules; its space group is thought to be C_{2h}^4.

(*ax*) The two studies that have been made of **Magnus' green salt,** $\mathbf{[Pt(NH_3)_4]PtCl_4}$, do not agree in the height of its one-molecule tetragonal unit. The following atomic positions, suggested in **1932**, 119, are not adequately established by the published data:

Pt: 000; 00½ Cl: ±(uv0); ±(vū0) with u=0.18, v=0.32
NH_3: ±(u'v'½); ±(v'ū'½) with u'=0.40, v'=0.11.

In **1931**, 193 it is said that Magnus' red salt has not only the same composition as the green salt but a cell of similar size and shape ($a_0 = 6.293$ A, $c_0 = 5.25$ A). Another determination (**1932**, 119) concludes that it is orthorhombic with $a_0 = 7.9$ A, $b_0 = 8.2$ A, $c_0 = 7.9$ A.

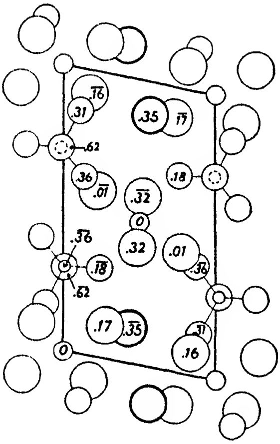
(*ay*) The unit cube of $\mathbf{Zn(ClO_4)_2 \cdot 4NH_3}$ is said to contain four molecules. It would be interesting to establish, by further chemical analyses, that this salt is really a tetrammoniate and not a hexammoniate.

(*az*) A recent study of $\mathbf{CuSO_4 \cdot 5H_2O}$, based on photographic data and a Fourier analysis of some spectrometric measurements, has led to an arrangement which places the copper atoms in its bimolecular triclinic unit in the symmetry centers 000 and ½½0. The other atoms are in general positions ±(xyz) of C_i^1 with the parameters of Table IV.

As can be seen from Figure 316 the water molecules are of two kinds. Four of them are coordinated with the copper atoms. The fifth, like zeolitic water, occupies a hole in the structure, its neighbors being two

TABLE IV. PARAMETERS OF THE ATOMS IN $CuSO_4 \cdot 5H_2O$

Atom	*No. per cell*	*x*	*y*	*z*
Cu(1)	1	0	0	0
Cu(2)	1	½	½	0
S	2	0	0.28	0.64
O(1)	2	0.89	.15	.69
O(2)	2	.24	.31	.82
O(3)	2	.86	.38	.64
O(4)	2	.02	.30	.38
H_2O(1)	2	.83	.08	.16
H_2O(2)	2	.29	.11	.17
H_2O(3)	2	.48	.41	.32
H_2O(4)	2	.76	.42	.01
H_2O(5)	2	.43	.12	.65



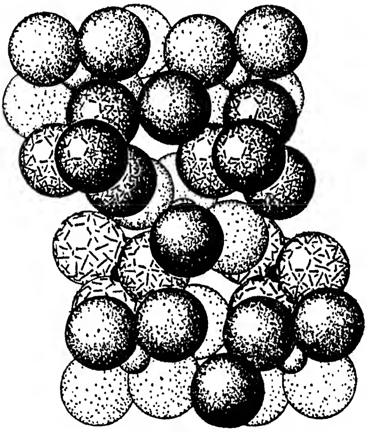


FIG. 316*a*.—(*left*) A projection of the triclinic $CuSO_4 \cdot 5H_2O$ arrangement viewed down the c-axis (after **1934**, 15a). The smallest circles are S atoms, the largest are H_2O molecules. Non-coordinated H_2O molecules are thickened. Atoms of the SO_4 ions are connected by light lines.

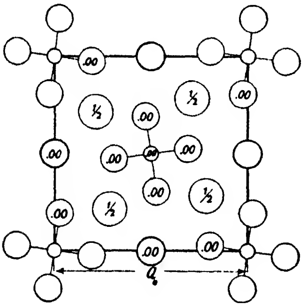
FIG. 316*b*.—(*right*) A packing drawing of *a*. The sulfate oxygens are line-shaded; small black S atoms show in two of the SO_4 groups. All H_2O molecules, whether coordinated with the Cu atoms or not, are dot-shaded.

water molecules and two sulfate oxygen atoms. Each copper atom is surrounded by an octahedron of atoms. Four of these are its coordinated water molecules situated approximately at the corners of a square, the other two, farther away, are oxygens from different sulfate groups.

(*ba*) Three unit cells have been suggested for **$[Pd(NH_3)_4]Cl_2 \cdot H_2O$** and its platinum analogue. The small one-molecule and the large four-molecule prisms are presumably wrong. The most recent study (**1934**, 71), using Laue and spectral photographic data, places the atoms of the two-molecule cells (Table I) in the following special positions of D_{4h}^5:

Pd: (a) $000; \frac{1}{2}\frac{1}{2}0$ H_2O: (d) $\frac{1}{2}00; 0\frac{1}{2}0$
Cl: (h) $u, u+\frac{1}{2}, \frac{1}{2}; \frac{1}{2}-u, u, \frac{1}{2}; u+\frac{1}{2}, \bar{u}, \frac{1}{2}; \bar{u}, \frac{1}{2}-u, \frac{1}{2}$ with $u=0.285$
N: (i) $uv0; v\bar{u}0; v+\frac{1}{2}, u+\frac{1}{2}, 0; u+\frac{1}{2}, \frac{1}{2}-v, 0; \bar{u}\bar{v}0; \bar{v}u0;$
$\frac{1}{2}-v, \frac{1}{2}-u, 0; \frac{1}{2}-u, v+\frac{1}{2}, 0$ with $u=0.194, v=0.027$.

Four coordinated NH_3 molecules are arranged about a central palladium atom at the corners of a square (NH_3-Pd=2.02 A). The extent to which packing prevails in basal planes of this structure and the way the H_2O molecules lie in holes present in these planes can best be seen from Figure 317.



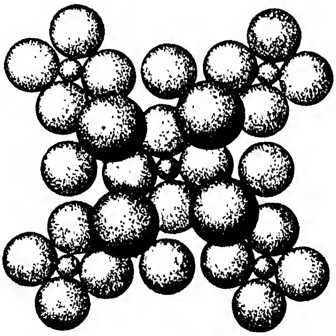


FIG. 317a.—(*left*) The atomic arrangement assigned to tetragonal $Pd(NH_3)_4Cl_2 \cdot H_2O$ as projected on its c-face. The largest circles are Cl ions, the smallest are Pd atoms. Intermediate circles are NH_3 if light in outline, H_2O if heavy.

FIG. 317b.—(*right*) A packing drawing of *a*. The H_2O and NH_3 molecules are not distinguished.

(*bb*) The rhombohedral unit found for **$AlCl_3 \cdot 6H_2O$**, and for the isomorphous **$CrCl_3 \cdot 6H_2O$**, contains two molecules. An atomic arrangement of both salts, based on D_{3d}^6, has been determined as:

Al: (b) $000; \frac{1}{2}\frac{1}{2}\frac{1}{2}$
Cl: (e) $u, \frac{1}{2}-u, \frac{1}{4}; \frac{1}{2}-u, \frac{1}{4}, u; \frac{1}{4}, u, \frac{1}{2}-u; \bar{u}, u+\frac{1}{2}, \frac{3}{4}; u+\frac{1}{2}, \frac{3}{4}, \bar{u}; \frac{3}{4}, \bar{u}, u+\frac{1}{2}$ with $u=0.51$
O: (f) $\pm(xyz); \pm(zxy); \pm(yzx); \pm(y+\frac{1}{2}, x+\frac{1}{2}, z+\frac{1}{2}); \pm(x+\frac{1}{2}, z+\frac{1}{2}, y+\frac{1}{2});$
$\pm(z+\frac{1}{2}, y+\frac{1}{2}, x+\frac{1}{2})$ with $x=0.26, y=0.16, z=-0.04$.

(*bc*) The two-molecule cells of **$MgSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$** and of the many crystals isomorphous with it have arrangements developed from

C_{2h}^5. A structure deduced from an elaborate consideration of photographic data has all atoms except magnesium in the general positions: (e) $\pm(xyz)$; $\pm(x+\frac{1}{2}, \frac{1}{2}-y, z)$, with the parameters listed in Table V. Mg atoms are at (a) 000; $\frac{1}{2}\frac{1}{2}0$. This arrangement can scarcely be correct because while the NH_4-O and Mg-H_2O separations are satisfactory, sulfate oxygens belonging to different SO_4 groups (such as A and B in Figure 318) are much too near together (O-O = ca 2.10 A).

TABLE V. PARAMETERS OF THE ATOMS IN $MgSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$

Atom	*x*	*y*	*z*
NH_4	0.120	0.357	0.345
S	.090	.635	.260
O(1)	.153	.746	.376
O(2)	−.032	.656	.020
O(3)	.227	.566	.225
O(4)	.012	.571	.419
$H_2O(1)$	.108	.127	.094
$H_2O(2)$	.168	−.084	.290
$H_2O(3)$	.123	−.062	−.150

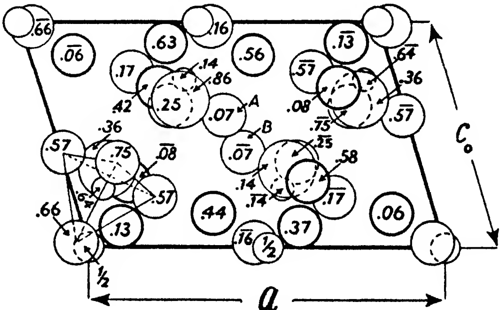


FIG. 318.—The unit cell of the structure proposed for $MgSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$ as projected on its b-face. The smallest circles are S atoms, the largest NH_4 ions. Circles slightly larger than S are Mg ions. Molecules of H_2O are distinguished from sulfate O atoms by being heavily ringed.

(*bd*) The monoclinic units of $\mathbf{MgBr_2 \cdot 6H_2O}$ and $\mathbf{MgCl_2 \cdot 6H_2O}$ contain two molecules. Photographic data have been used in choosing the following arrangement, based on C_{2h}^3:

Mg: (a) 000; $\frac{1}{2}\frac{1}{2}0$ Cl or Br: (i) u0v; $\bar{u}0\bar{v}$; $u+\frac{1}{2}, \frac{1}{2}, v$; $\frac{1}{2}-u, \frac{1}{2}, \bar{v}$

For Cl, u = 0.320, v = 0.615; for Br, u = 0.318, v = 0.615.

$H_2O(1)$: (i) u′0v′; etc. with u′ = 0.20, v′ = 0.11 for both salts
$H_2O(2)$: (j) $\pm(xyz)$; $\pm(x\bar{y}z)$; $\pm(x+\frac{1}{2}, y+\frac{1}{2}, z)$; $\pm(x+\frac{1}{2}, \frac{1}{2}-y, z)$

with x = 0.96, y = 0.20 for both salts, z = 0.230 for the chloride and 0.225 for the bromide.

(*be*) The four molecules in the elongated tetragonal unit of $\mathbf{NiSO_4 \cdot 6H_2O}$ are arranged according to the demands of the enantiomorphic pair of space groups D_4^4 and D_4^8. Expressed in terms of D_4^4 the atomic positions found for this crystal are:

Ni: (a) $uu0;\ \bar{u}\bar{u}\tfrac{1}{2};\ u+\tfrac{1}{2},\ \tfrac{1}{2}-u,\ \tfrac{3}{4};\ \tfrac{1}{2}-u,\ u+\tfrac{1}{2},\ \tfrac{1}{4}$ with $u=0.71$
S: (a) $u'u'0$; etc. with $u'=0.21$
H_2O and O: (b) $xyz;\ y+\tfrac{1}{2},\ \tfrac{1}{2}-x,\ z+\tfrac{3}{4};\ \bar{x},\ \bar{y},\ z+\tfrac{1}{2};\ \tfrac{1}{2}-y,\ x+\tfrac{1}{2},\ z+\tfrac{1}{4};$
$\tfrac{1}{2}-x,\ y+\tfrac{1}{2},\ \tfrac{1}{4}-z;\ \bar{y},\ \bar{x},\ \tfrac{1}{2}-z;\ x+\tfrac{1}{2},\ \tfrac{1}{2}-y,\ \tfrac{3}{4}-z;\ yx\bar{z}$

with the parameters of Table VI.

TABLE VI. PARAMETERS OF THE OXYGEN ATOMS IN $NiSO_4 \cdot 6H_2O$

Atom	*x*	*y*	*z*
O(1)	0.12	0.12	0.068
O(2)	.43	.17	.000
$H_2O(1)$	.67	.45	.054
$H_2O(2)$	.97	.75	.054
$H_2O(3)$	.56	.86	.077

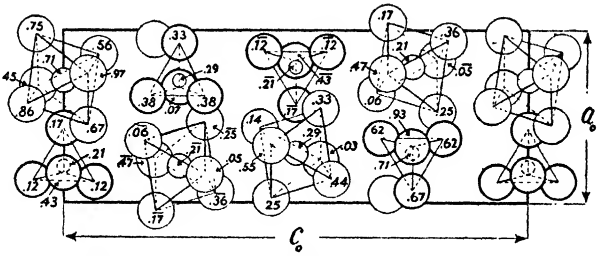


FIG. 319*a*.—A projection of the tetragonal $NiSO_4 \cdot 6H_2O$ grouping upon one of its a-faces. In this figure the sulfate oxygens are heavily ringed, the H_2O molecules lightly outlined. Medium sized circles, at the centers of the water octahedra, are the Ni atoms.

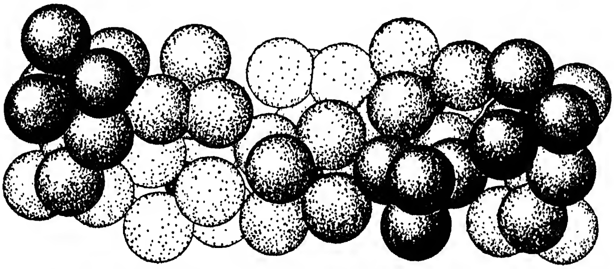


FIG. 319*b*.—A packing drawing of *a*. The Ni atoms appear as black spheres within their H_2O octahedra; S atoms do not show.

The structure as a whole is a packing of SO_4 tetrahedra and $(Ni \cdot 6H_2O)$ octahedra (Figure 319).

(*bf*) In a recent study a set of atomic positions, developed from C_{31}^1, has been proposed for $SrCl_2 \cdot 6H_2O$. They are:

Sr: (a) 000 Cl: (d) $\frac{1}{3}\frac{2}{3}u$; $\frac{2}{3}\frac{1}{3}\bar{u}$ with $u=\frac{1}{2}$
H_2O: (g) $\pm(xyz); \pm(y-x, \bar{x}, z); \pm(\bar{y}, x-y, z)$ with $x=y=0.387$, $z=0.0$.

The published data, which are scanty, are insufficient to establish this structure.

(*bg*) The previously chosen unit for **$MgPt(CN)_4 \cdot 7H_2O$** ($a_0=14.6$ A, $c_0=3.13$ A) was too small. The true cell is twice as high, $c_0=6.26$ A, and contains four molecules.

(*bh*) The space group of the four-molecule cell of $3CdSO_4 \cdot 8H_2O$ is said to be C_{2h}^6.

(*bi*) Estimates of the intensities of powder lines have been used to suggest the following atomic arrangement, based on D_{4h}^1, for **$SrO_2 \cdot 8H_2O$**:

Sr: (a) 000 O: (h) $\frac{1}{2}\frac{1}{2}w$; $\frac{1}{2}\frac{1}{2}\bar{w}$ with $w=0.10$
H_2O: (r) $\pm(uuv); \pm(u\bar{u}v); \pm(\bar{u}\bar{u}v); \pm(\bar{u}uv)$ with $u=0.20$, $v=0.25$.

In this arrangement strontium atoms are surrounded by cubes of H_2O molecules with the somewhat short Sr-H_2O distance of 2.26 A; inside the O_2 group the atomic separation is 1.11 A.

(*bj*) The large unit found for $2Na_3PO_4 \cdot NaF \cdot 19H_2O$ holds 40 molecules. The data are those demanded by O_h^8.

(*bk*) The unit cubes of several **phosphotungstic** and **phosphomolybdic acids** and their salts crystallizing with 30±1 molecules of H_2O have been found to contain eight molecules. Their space group is said to be O_h^7.

Powder photographic data have been used to determine the shape and size of the $PW_{12}O_{40}$ anion in the partially dehydrated $H_3PW_{12}O_{40} \cdot 5$, or 7, H_2O and to suggest probable positions for the H_2O molecules. The unit cube of this lower hydrate contains two molecules; the atoms of its anions are in the following special positions of O_h^4:

P: (2a) $000; \frac{1}{2}\frac{1}{2}\frac{1}{2}$
W: (24u) $uuv; u\bar{u}\bar{v}; \bar{u}u\bar{v}; \bar{u}\bar{u}v; vuu; \bar{v}u\bar{u}; \bar{v}\bar{u}u; v\bar{u}\bar{u}; uvu; \bar{u}\bar{v}u; u\bar{v}\bar{u}; \bar{u}v\bar{u};$
$\frac{1}{2}-u, \frac{1}{2}-u, \frac{1}{2}-v; \frac{1}{2}-u, u+\frac{1}{2}, v+\frac{1}{2}; u+\frac{1}{2}, \frac{1}{2}-u, v+\frac{1}{2};$
$u+\frac{1}{2}, u+\frac{1}{2}, \frac{1}{2}-v; \frac{1}{2}-v, \frac{1}{2}-v, \frac{1}{2}-u; v+\frac{1}{2}, \frac{1}{2}-u, u+\frac{1}{2};$
$v+\frac{1}{2}, u+\frac{1}{2}, \frac{1}{2}-u; \frac{1}{2}-v, u+\frac{1}{2}, u+\frac{1}{2}; \frac{1}{2}-u, \frac{1}{2}-v, \frac{1}{2}-u;$
$u+\frac{1}{2}, v+\frac{1}{2}, \frac{1}{2}-u; \frac{1}{2}-u, v+\frac{1}{2}, u+\frac{1}{2}; u+\frac{1}{2}, \frac{1}{2}-v, u+\frac{1}{2}$

with $u=0.205$, $v=0.006$

O(1): (8d) $u'u'u'; \bar{u}'u'\bar{u}'; \frac{1}{2}-u', \frac{1}{2}-u', \frac{1}{2}-u'; u'+\frac{1}{2}, \frac{1}{2}-u', u'+\frac{1}{2};$
$u'\bar{u}'\bar{u}'; \bar{u}'\bar{u}'u'; \frac{1}{2}-u', u'+\frac{1}{2}, u'+\frac{1}{2}; u'+\frac{1}{2}, u'+\frac{1}{2}, \frac{1}{2}-u'$

with $u=0.081$

O(2): (24u) $u_1u_1v_1$; etc. with $u_1=-0.080$, $v_1=-0.234$
O(3): (24u) $u_2u_2v_2$; etc. with $u_2=0.123$, $v_2=0.292$
O(4): (24u) $u_3u_3v_3$; etc. with $u_3=-0.312$, $v_3=-0.008$.

The shape of one of these $PW_{12}O_{40}$ ions is shown in Figure 320. It consists of a central PO_4 tetrahedron and 12 surrounding WO_6 octahedra that share oxygen atoms with it. The H_2O molecules are considered to be of two sorts: three in the positions: (6e) $00\frac{1}{2}$; $\frac{1}{2}00$; $0\frac{1}{2}0$; $\frac{1}{2}\frac{1}{2}0$; $\frac{1}{2}0\frac{1}{2}$; $0\frac{1}{2}\frac{1}{2}$ and four at (4e) $\frac{3}{4}\frac{3}{4}\frac{3}{4}$; $\frac{3}{4}\frac{1}{4}\frac{1}{4}$; $\frac{1}{4}\frac{3}{4}\frac{1}{4}$; $\frac{1}{4}\frac{1}{4}\frac{3}{4}$, if the crystal is a heptahydrate.

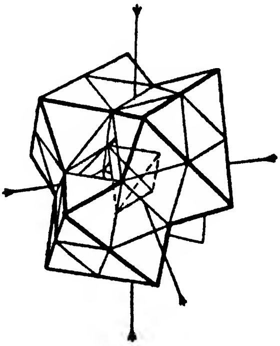


FIG. 320.—The $PW_{12}O_{40}$ ion is considered to have a shape suggested by this diagram. The central P atom is surrounded by four O atoms at the corners of the dotted tetrahedron. About it are 12 oxygen octahedra which share atoms with one another and with the PO_4 group and which have W atoms at their centers (after 1934, 131).

(*bl*) The unit assigned to the complex phosphate **wavellite, $4(PO_4)Al\cdot 2Al(OH)_3\cdot 9H_2O$,** is bimolecular.

(*bm*) The unit cell of **legrandite** has one molecule of the composition $Zn_{14}(AsO_4)_9OH\cdot 12H_2O$.

(*bn*) The monoclinic unit given to $[Co^{CO_3}_{(NH_3)_4}]_2SO_4\cdot 3H_2O$ contains two molecules; the space group is thought to be C_s^1.

(*bo*) Two molecules are found in the unit of $MgNH_4AsO_4\cdot 6H_2O$; its space group is C_{2v}^7.

(*bp*) The structure recently developed for **$LiClO_4\cdot 3H_2O$** differs from that previously found for the isomorphous $LiI\cdot 3H_2O$ (*f*) in the positions of the lithium atoms. In the perchlorate, atoms are in the following special positions of C_{6v}^4:

Li: (a) $00u_1$; $0, 0, u_1+\frac{1}{2}$ with $u_1=0.25$
Cl: (b) $\frac{1}{3}\frac{2}{3}u'$; $\frac{2}{3}, \frac{1}{3}, u'+\frac{1}{2}$ with $u'=0$
O(1): (b) $\frac{1}{3}\frac{2}{3}w$; $\frac{2}{3}, \frac{1}{3}, w+\frac{1}{2}$ with $w=0.278$
O(2): (c) $u\bar{u}v$; $2\bar{u}, \bar{u}, v$; $u, 2u, v$; $\bar{u}, u, v+\frac{1}{2}$; $2u, u, v+\frac{1}{2}$; $\bar{u}, 2\bar{u}, v+\frac{1}{2}$

with $u=0.439$, $v=-0.092$

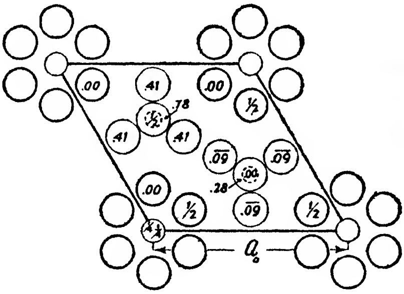
H_2O: (c) $u_2\bar{u}_2v_2$; etc. with $u_2=0.125$, $v_2=0.50$.

This arrangement, which coordinates six H_2O molecules about each lithium atom (Figure 321), is practically identical with one found from quantitative spectrometric data.*

---

* Unpublished measurements of R. B. Corey in this laboratory. The parameters derived from this study are $u_1(Li)=0.25$, $u'(Cl)=0$, $w(O)=0.265$, $u(O)=0.435$, $v(O)=-0.09$, $u_2(H_2O)=0.125$, $v_2(H_2O)=0.50$.

It is probable that the lithium atoms in $LiI \cdot 3H_2O$ should be in (a) $0 0 u_1$; $0, 0, u_1+\frac{1}{2}$ instead of the earlier (b) $\frac{1}{3}\frac{2}{3}u_1$; $\frac{2}{3}, \frac{1}{3}, u_1+\frac{1}{2}$. Photographic data lead to the parameters: $u_1(Li)=0.25$, $u'(I)=0$, $u_2(H_2O)=0.142$, $v_2(H_2O)=0.50$.



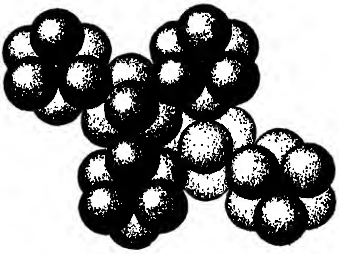
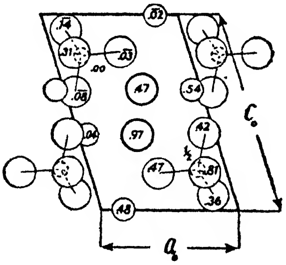


FIG. 321*a*.—(*left*) A basal projection of the structure found for $LiClO_4 \cdot 3H_2O$. Li atoms are at the corners of the diagram surrounded by the heavily outlined water molecules.

FIG. 321*b*.—(*right*) A packing drawing of *a* showing the tetrahedral ClO_4 ions and (black) Li ions equidistant from six H_2O molecules. The O atoms and H_2O molecules, of equal size, are not distinguished by different shadings.



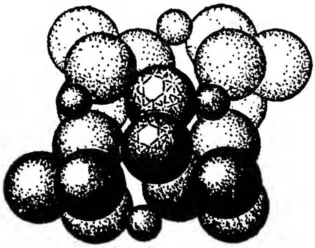


FIG. 321*c*.—(*left*) A projection upon its b-face of the monoclinic structure deduced for $Li_2SO_4 \cdot H_2O$. Atoms of the SO_4 ions are connected by light lines; the H_2O molecules are heavily ringed.

FIG. 321*d*.—(*right*) A packing drawing of *c* with the H_2O molecules distinguished by line-shading. The S atoms within their tetrahedra cannot be seen.

(*bq*) The hexagonal unit prism of $\mathbf{Ba(ClO_4)_2 \cdot 3H_2O}$ is bimolecular. The space group is reported to be C_6^6 or C_{6h}^2.

(*br*) The atoms of the two $\mathbf{Li_2SO_4 \cdot H_2O}$ molecules contained within the unit cell are in general positions of C_2^2 with the coordinates (a) xyz; $\bar{x}, y+\frac{1}{2}, \bar{z}$. Parameters, determined from photographic data, are those of Table VII. In this structure (Figure 321c and d) the lithium atoms are

TABLE VII. PARAMETERS OF THE ATOMS IN $Li_2SO_4 \cdot H_2O$

Atom	*x*	*y*	*z*
S	0.208	0.000	−0.211
O(1)	.153	−.139	−.083
O(2)	.500	−.014	−.192
O(3)	.078	−.078	−.397
O(4)	.161	.305	−.197
H_2O	.569	.472	−.386
Li(1)	−.069	.542	−.386
Li(2)	.167	.478	.003

surrounded by tetrahedra consisting of three sulfate oxygen atoms and one H_2O molecule.

(*bs*) The unit prism of $\mathbf{Na_2CO_3 \cdot H_2O}$ contains four molecules; its space group is said to be V_h^{16}.

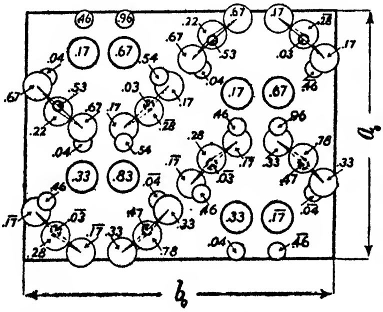
(*bt*) Four molecules are within the cell of $\mathbf{AgNO_3 \cdot 2NH_3}$. The space group is C_{2v}^{10}.

Miscellaneous Inorganic Compounds

(*ca*) The cube lengths found for a large number of **atopites** and atopite-like minerals, and for ochers of calcium and of lead vary between ca 10.25 A and ca 10.43 A.

(*cb*) A partial atomic arrangement for **azurite,** $\mathbf{2CuCO_3 \cdot Cu(OH)_2}$, has been based on some rotation photographs and spectrometer data. Copper atoms have been placed in (a) 000; $0\frac{1}{2}\frac{1}{2}$ and in general positions of C_{2h}^5: (e) $\pm(xyz)$; $\pm(\bar{x}, y+\frac{1}{2}, \frac{1}{2}-z)$ with $x=0.25$, $y=0.486$, $z=0.083$. Suggested parameters for the other atoms are not proved by the existing data.

(*cc*) The mineral **hambergite,** $\mathbf{Be_2BO_3(OH)}$, has been given a structure which explains both a series of spectrometric intensities and the qualita-



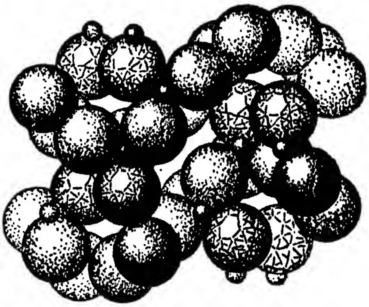


FIG. 322*a*.—(*left*) A projection upon the c-face of the orthorhombic structure assigned to hambergite, $Be_2BO_3(OH)$. Atoms of the BO_3 groups are connected by light lines. Intermediate circles represent Be atoms; the (OH) groups are heavily ringed.

FIG. 322*b*.—(*right*) A packing drawing of *a*. Small spheres are the Be atoms; the B atoms do not show. Hydroxyl groups are line-shaded.

TABLE VIII. THE CRYSTAL STRUCTURES OF MISCELLANEOUS INORGANIC COMPOUNDS

Substance, symmetry and type			a_o	b_o	c_o	*Space group*	*No. mol. per cell*	*References*
Arsenoklasite $Mn_3(AsO_4)_2 \cdot 2Mn(OH)_2$	Ort.		9.19	18.01	5.79		4	1931, 10.
$AsI_3 \cdot 3S_8$	Hex.		14.2		4.48	C_{3v}^1	1	1931, 186.
Atopites $(Ca, Mn, Na)_2Sb_2(O, OH, F)_7$	Cub.	(*ca*)						1932, 323, 324; 1933, 4.
Azurite $2CuCO_3 \cdot Cu(OH)_2$	Mon.	(*cb*)	4.96	5.83 $\beta = 87°36'$	10.27	C_{2h}^5	2	1932, 72; 1933, 71.
Bindheimite $Pb_2Sb_2O_7$	Cub.	(*ca*)	10.44				8	1933, 316.
Binnite $(Cu, Fe)_{12}As_4S_{13}$	Cub.	(*cj*)	10.19			T_d^3	2	1934, 205.
Boleite								1930, 105b.
Boracite $Mg_3ClB_7O_{13}$ (low temp. form)	Ort.	(*aa*), (*ck*)	17.07	17.07	12.07		8	1932, 307; 1933, 201; 1934, 171.
Boracite $Mg_3ClB_7O_{13}$ (high temp. form, >265° C)	Cub.	(*ck*)	12.1				4	1932, 307; 1934, 171.
Bournonite $CuPbSbS_3$	Ort.		8.10	8.65	7.75	V_h^{13}	4	1932, 343.
$CHI_3 \cdot 3S_8$	Hex.		14.1		4.44	C_{3v}^1	1	1931, 186.
Cumengeite								1930, 105b.
Hambergite $Be_2BO_3(OH)$	Ort.	(*cc*)	9.73	12.18	4.42	V_h^{15}	8	1931, 495.
Hanksite $9Na_2SO_4 \cdot 2Na_2CO_3 \cdot KCl$	Hex.		10.52		21.25	C_{6h}^2	2	1931, 134.
Koppite $(Ca, Ce, Na, K)_2(Cb, Fe)_2O_6(O, OH, F)$	Cub.	(*ca*)	10.37				8	1931, 57.
Lewisite $(Ca, Fe, Na)_2(Sb, Ti)_2(O, OH)_7$	Cub.	(*ca*)	10.269				8	1932, 298.
Malachite $CuCO_3 \cdot Cu(OH)_2$	Mon.	(*cd*)	9.38	11.95 $\beta = 91°3'$	3.18	C_{2h}^5	4	1932, 71; 1933, 71.

Substance, symmetry and type			a_0	b_0	c_0	*Space group*	*No. mol. per cell*	*References*
Microlite $(Ca, Na)_2(Ta, Cb)_2(O, F)_7$	Cub.	(*ca*)	10.381				8	1933, 374.
Northupite $Na_2Mg(CO_3)_2 \cdot NaCl$	Cub.	(*ce*)	13.98			T_h^4	16	1931, 134, 413; 1933, 491.
Brominated Northupite $Na_2Mg(CO_3)_2 \cdot NaBr$	Cub.	(*ce*)	14.17			T_h^4	16	1931, 413.
Triphosphonitrile $(PNCl_2)_3$	Ort.		14.00	6.16	12.94	V_h^{16}	4	1932, 235.
Tetraphosphonitrile $(PNCl_2)_4$	Tet.		10.79		5.93	C_{4h}^4	2	1932, 235.
Potassium Trithionate $K_2S_3O_6$	Ort.	(*cf*)	9.77	13.63	5.76	V_h^{16}	4	1934, 305, 305b.
Potassium Pyrosulfite $K_2S_2O_5$	Mon.	(*cg*)	6.95	6.19	7.55	C_{2h}^2	2	1932, 487, 490.
Pesudoboleite	Tet.	(*ac*)						1930, 105b.
Pyrrhite	Cub.	(*ca*)	10.40				8	1932, 296.
Pyroaurite $Fe(OH)_3 \cdot 3Mg(OH)_2 \cdot 3H_2O$	Hex.	(*ch*)	3.089		23.23		$\frac{3}{4}$	1931, 11.
Pyrochlore $(Na, Ca)_2(Cb, Ti)_2(O, F)_7$	Cub.	(*ca*)	10.376				8	1930, 391.
Romeite $(Ca, Na, Mn)_2Sb_2(O, OH, F)_7$	Cub.	(*ca*)	10.261				8	1932, 324, 496; 1933, 316.
Schneebergite $(Ca, Na, Fe)_2Sb_2O_6(OH)$	Cub.	(*ca*)	10.296				8	1932, 496.
Sulphohalite $2Na_2SO_4 \cdot NaCl \cdot NaF$	Cub.	(*cl*)	10.08			O_h^5	4	1934, 347.
Tetradymite	Hex.	(*cm*)	10.31		$\alpha = 24°10'$		1	1934, 332.
Tychite $2MgCO_3 \cdot 2Na_2CO_3 \cdot Na_2SO_4$	Cub.	(*ce*)	13.90			T_h^4	8	1931, 413; 1933, 491.
Voltaites	Cub.	(*ad*), (*ci*)						1932, 171; 1933, 150, 151.
Basic Zinc Chloride $ZnCl_2 \cdot 4Zn(OH)_2$	Hex.		12.56		15.84		8	1933, 131.

tive data from oscillation photographs. Atoms in its eight-molecule unit are in general positions (c) $\pm(xyz)$; $\pm(x+\frac{1}{2}, \frac{1}{2}-y, \bar{z})$; $\pm(\bar{x}, y+\frac{1}{2}, \frac{1}{2}-z)$; $\pm(\frac{1}{2}-x, \bar{y}, z+\frac{1}{2})$ of V_h^{15} with the coordinates listed in Table IX. The axes of this description are the same as those of **1930**, 352, p. 64.

As can be seen from Figure 322a and b the grouping consists of linked BO_3 triangles and $Be(O_3OH)$ tetrahedra. Each oxygen atom is shared by one B and two Be atoms; OH groups join two Be atoms.

TABLE IX. PARAMETERS OF THE ATOMS IN HAMBERGITE

Atom	*No. per cell*	*x*	*y*	*z*
Be(1)	8	−0.031	0.183	0.458
Be(2)	8	.236	.069	.458
B	8	.117	.103	−.028
O(1)	8	.031	.183	−.167
O(2)	8	.097	.103	.278
O(3)	8	.194	.037	−.167
OH	8	−.167	.183	.167

(*cd*) The copper atoms of the four molecules of **$CuCO_3 \cdot Cu(OH)_2$** lying in the unit cell of **malachite** are reported to be in two sets of general positions of C_{2h}^5: (e) $\pm(xyz)$; $\pm(\frac{1}{2}-x, y+\frac{1}{2}, \bar{z})$ with the parameters $x=0$, $y=0.208$, $z=0.125$, $x'=0.264$, $y'=0.104$, $z'=0.625$. The other atomic parameters have not been found.

(*ce*) Some photographic data have been used in assigning a structure to **northupite, $Na_2Mg(CO_3)_2 \cdot NaCl$**. According to this arrangement the 16 molecules of its unit cube are in the following special and general positions of T_h^4 (**1930**, 352, p. 125):

Mg: (16c) $\frac{5}{8}\frac{5}{8}\frac{5}{8}$; $\frac{5}{8}\frac{7}{8}\frac{7}{8}$; $\frac{7}{8}\frac{5}{8}\frac{7}{8}$; $\frac{7}{8}\frac{7}{8}\frac{5}{8}$ and 3 sets of similar points about $0\frac{1}{2}\frac{1}{2}$, $\frac{1}{2}0\frac{1}{2}$ and $\frac{1}{2}\frac{1}{2}0$
Cl: (16b) $\frac{1}{8}\frac{1}{8}\frac{1}{8}$; $\frac{1}{8}\frac{3}{8}\frac{3}{8}$; $\frac{3}{8}\frac{3}{8}\frac{1}{8}$; $\frac{3}{8}\frac{1}{8}\frac{3}{8}$ and 3 sets of similar points about $0\frac{1}{2}\frac{1}{2}$, $\frac{1}{2}0\frac{1}{2}$ and $\frac{1}{2}\frac{1}{2}0$
C: (32b) uuu; $u\bar{u}\bar{u}$; $\bar{u}u\bar{u}$; $\bar{u}\bar{u}u$; $\frac{1}{4}-u, \frac{1}{4}-u, \frac{1}{4}-u$; $\frac{1}{4}-u, u+\frac{1}{4}, u+\frac{1}{4}$; $u+\frac{1}{4}, \frac{1}{4}-u, u+\frac{1}{4}$; $u+\frac{1}{4}, u+\frac{1}{4}, \frac{1}{4}-u$ and similar points about $0\frac{1}{2}\frac{1}{2}$, $\frac{1}{2}0\frac{1}{2}$ and $\frac{1}{2}\frac{1}{2}0$ with $u(C)=0.405$
Na: (48c) $u00$; $\bar{u}00$; $0u0$; $0\bar{u}0$; $00u$; $00\bar{u}$; $\frac{1}{4}-u, \frac{1}{4}, \frac{1}{4}$; $u+\frac{1}{4}, \frac{1}{4}, \frac{1}{4}$; $\frac{1}{4}, \frac{1}{4}-u, \frac{1}{4}$; $\frac{1}{4}, u+\frac{1}{4}, \frac{1}{4}$; $\frac{1}{4}, \frac{1}{4}, \frac{1}{4}-u$; $\frac{1}{4}, \frac{1}{4}, u+\frac{1}{4}$ and similar points about $0\frac{1}{2}\frac{1}{2}$, $\frac{1}{2}0\frac{1}{2}$, $\frac{1}{2}\frac{1}{2}0$ with $u(Na)=0.225$
O: (g) xyz; $x\bar{y}\bar{z}$; $\bar{x}y\bar{z}$; $\bar{x}\bar{y}z$; zxy; $\bar{z}x\bar{y}$; $\bar{z}\bar{x}y$; $z\bar{x}\bar{y}$; yzx; $\bar{y}\bar{z}x$; $y\bar{z}\bar{x}$; $\bar{y}z\bar{x}$; $\frac{1}{4}-x, \frac{1}{4}-y, \frac{1}{4}-z$; $\frac{1}{4}-x, y+\frac{1}{4}, z+\frac{1}{4}$; $x+\frac{1}{4}, \frac{1}{4}-y, z+\frac{1}{4}$; $x+\frac{1}{4}, y+\frac{1}{4}, \frac{1}{4}-z$; $\frac{1}{4}-z, \frac{1}{4}-x, \frac{1}{4}-y$; $z+\frac{1}{4}, \frac{1}{4}-x, y+\frac{1}{4}$; $z+\frac{1}{4}, x+\frac{1}{4}, \frac{1}{4}-y$; $\frac{1}{4}-z, x+\frac{1}{4}, y+\frac{1}{4}$; $\frac{1}{4}-y, \frac{1}{4}-z, \frac{1}{4}-x$; $y+\frac{1}{4}, z+\frac{1}{4}, \frac{1}{4}-x$; $\frac{1}{4}-y, z+\frac{1}{4}, x+\frac{1}{4}$; $y+\frac{1}{4}, \frac{1}{4}-z, x+\frac{1}{4}$ and similar points about $0\frac{1}{2}\frac{1}{2}$, $\frac{1}{2}0\frac{1}{2}$, $\frac{1}{2}\frac{1}{2}0$. The chosen parameters are $x=0.392$, $y=0.348$, $z=0.475$.

The arrangement given to tychite, $Na_4Mg_2(CO_3)_4 \cdot Na_2SO_4$, is like this northupite grouping with Na_2SO_4 in place of 2NaCl. The eight sulfur atoms in the unit cube are at (8f) 000; $\frac{1}{2}\frac{1}{2}0$; $\frac{1}{2}0\frac{1}{2}$; $0\frac{1}{2}\frac{1}{2}$; $\frac{1}{4}\frac{1}{4}\frac{1}{4}$; $\frac{1}{4}\frac{3}{4}\frac{3}{4}$; $\frac{3}{4}\frac{1}{4}\frac{3}{4}$; $\frac{3}{4}\frac{3}{4}\frac{1}{4}$. Sulfate oxygen atoms are in (32b) u'u'u'; etc. with u'(O)=0.062. The other atoms are placed as in northupite: Mg in (16c); C in (32b) with u=0.400; Na in (48c) with u=0.225 and carbonate oxygens in (g) of T_h^4 with x=0.375, y=0.352, z=0.473.

(*cf*) From spectral photographic data it has been found that the atoms in **potassium trithionate, $K_2S_3O_6$,** are in the following positions of V_h^{16}:

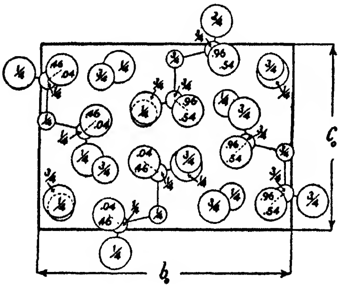
(c) $\pm(uv\frac{1}{4})$; $\pm(\frac{1}{2}-u, v+\frac{1}{2}, \frac{3}{4})$

(d) $\pm(xyz)$; $\pm(x+\frac{1}{2}, \frac{1}{2}-y, \frac{1}{2}-z)$;
$\pm(x, y, \frac{1}{2}-z)$; $\pm(x+\frac{1}{2}, \frac{1}{2}-y, z)$

with the parameters of Table X. In this structure (Figure 322c) S-O within the same ion is ca 1.50 A, S-S=2.19 A and the angle joining the three sulfur atoms is 103°.

TABLE X. PARAMETERS OF THE ATOMS IN $K_2S_3O_6$

Atom	*No. per cell*	*Position*	*x*	*y*	*z*
K(1)	4	(c)	0.131	0.089	0.25
K(2)	4	(c)	.180	−.236	.25
S(1)	4	(c)	.033	.319	.25
S(2)	4	(c)	.083	.472	.25
S(3)	4	(c)	.305	.472	.25
O(1)	4	(c)	−.125	.305	.25
O(2)	4	(c)	.347	.583	.25
O(3)	8	(d)	.083	.278	.042
O(4)	8	(d)	.361	.417	.042



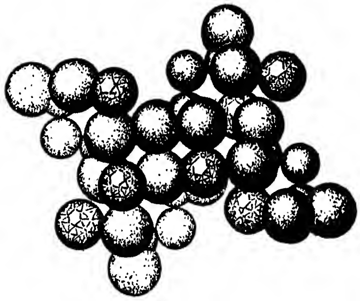


FIG. 322c.—(*left*) The structure found for $K_2S_3O_6$ projected on the a-face of its orthorhombic cell. Largest circles are O atoms, intermediate circles K ions. Atoms of the S_3O_6 ions are connected by light lines.

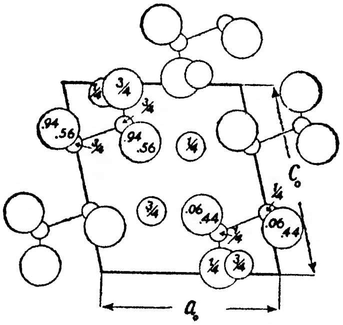
FIG. 322d.—(*right*) A packing drawing of c. The K ions are line-shaded. No significance is to be attached to the radii chosen for sulfur.

(*cg*) Estimated intensities on oscillation photographs have been used in choosing a structure for **potassium pyrosulfite, $K_2S_2O_5$**. The atoms in its two-molecule cell are placed in the following special and general positions of C_{2h}^2: (e) $\pm(u\frac{1}{4}v)$, (f) $\pm(xyz)$; $\pm(x, \frac{1}{2}-y, z)$ with the parameters of Table XI. The pyrosulfite ion resulting from this arrangement has the structure $O_3S\text{-}SO_2$ (Figure 323) with a S-S distance of 2.18 A.

(*ch*) It is natural to infer from the fractional number of molecules found in the unit of **pyroaurite** that either the formula, the cell size or the density is in error. Existing data contain no evidence for a larger cell and the formula is said to be substantially correct.

TABLE XI. PARAMETERS OF THE ATOMS IN $K_2S_2O_5$

Atom	*No. per cell*	*Position*	*x*	*y*	*z*
K(1)	2	(e)	0.22	0.25	0.95
K(2)	2	(e)	.65	.25	.67
S(1)	2	(e)	.70	.25	.22
S(2)	2	(e)	.01	.25	.32
O(1)	4	(f)	.07	.06	.24
O(2)	4	(f)	.63	.06	.31
O(3)	2	(e)	.67	.25	.03



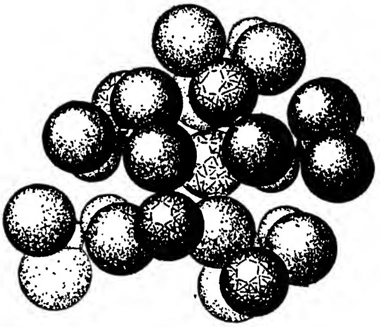


FIG. 323*a*.—(*left*) The monoclinic structure of $K_2S_2O_5$ projected on its b-face. Oxygen atoms are represented by the largest, S by the smallest circles. The light lines joining them outline the S_2O_5 ions.

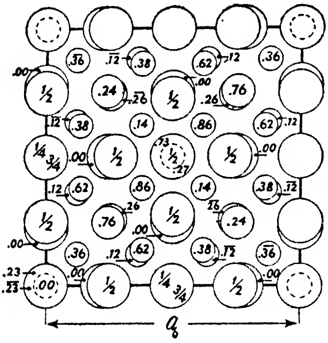
FIG. 323*b*.—(*right*) A packing drawing of *a*. The size given the S atoms was determined by convenience only. K ions are line-shaded.

(*ci*) A large number of the cubic or pseudo-cubic **voltaites** have been prepared and their unit cells measured (see Table XII). The composition of these sulfates is still uncertain though a recent study (1932, 171) places it as approximately $(SO_4)_{12}Fe_4^{+++}R_5^{++}R_2^{+}\cdot 16\text{-}18H_2O$.

(*cj*) A structure has been found for the complex sulfide **binnite, (Cu, Fe)$_{12}$As$_4$S$_{13}$**, which, except for the addition of two extra sulfur atoms and

TABLE XII. UNIT CUBE SIZE OF VOLTAITES

Voltaite	a_0	*Voltaite*	a_0
K-Cd compound	27.54	Rb-Cd compound	27.80
$K\text{-}Fe^{++}$	27.33	$Rb\text{-}Fe^{++}$	27.60
$K\text{-}Mn^{++}$	27.25	$Rb\text{-}Mn^{++}$	27.60
K-Zn	27.10	Rb-Zn	27.15
$NH_4\text{-}Cd$	27.85	Tl-Cd	27.69
$NH_4\text{-}Fe^{++}$	27.35	$Tl\text{-}Fe^{++}$	27.43
$NH_4\text{-}Mg$	27.42	$Tl\text{-}Mn^{++}$	27.71
$NH_4\text{-}Mn^{++}$	27.55	Tl-Zn	27.01



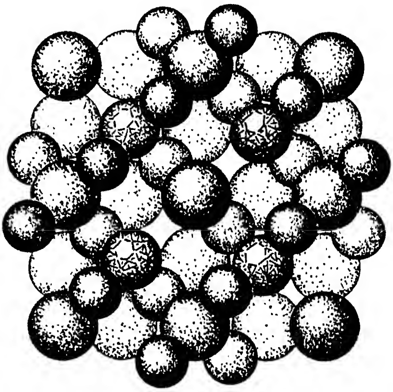


FIG. 324*a*.—(*left*) A cube face projection of the structure of binnite, $(Cu, Fe)_{12}As_4S_{13}$. The largest circles are (Cu, Fe), the smallest are S atoms.

FIG. 324*b*.—(*right*) A packing drawing showing the bottom half of the unit cube of binnite. The atoms have their neutral radii; As atoms are line-shaded.

somewhat altered parameters, is identical with that previously determined for tetrahedrite, $(Cu, Ag)_3(Sb, As)S_3$ [XV, (*p*), p. 280]. The binnite arrangement, as developed from photographic data, places the atoms of its two-molecule cube in positions (of T_d^3):

Cu, Fe(1): (12a) u00; etc. with u=0.225
Cu, Fe(2): (12h) $\frac{1}{2}0\frac{1}{4}$; etc.
As: (8a) u′u′u′; etc. with u′=0.255
S(1): (24g) vvw; etc. with v=0.122, w=0.363
S(2): (2a) 000; $\frac{1}{2}\frac{1}{2}\frac{1}{2}$.

The packing is that to be expected from neutral atoms. It is instructive to compare the atomic environments in this arrangement (Figure 324a and b) with those prevailing in enargite, Cu_3AsS_4 [XVIA, (*an*)]. All the sulfurs in enargite and those [in (24g)] which are common to both binnite and tetrahedrite have four metal atoms tetrahedrally placed about them. The two binnite sulfurs at 000 and $\frac{1}{2}\frac{1}{2}\frac{1}{2}$ are enclosed by six octahedrally grouped (Cu, Fe) atoms. In enargite the copper and arsenic atoms are tetrahedrally surrounded but in binnite and tetrahedrite the metal environments are more complex. Arsenic atoms and the Cu, Fe(1) atoms in (12a) have only three neighboring sulfurs; four sulfurs, however, are to be found about Cu, Fe(2) in (12h).

(*ck*) The mineral **boracite**, with eight molecules of the composition $Mg_6Cl_2B_{14}O_{26}$ in its orthorhombic unit, has recently been assigned one of the space groups C_{2v}^{12} or C_{2v}^{14}. Previous studies had preferred C_{2v}^{11}.

Above 265° C this mineral is cubic with a four-molecule cell. Possible space groups and structures have been discussed but no definite conclusions have been reached.

(*cl*) It has been shown that the photographically observed powder lines of **sulphohalite, $2Na_2SO_4 \cdot NaCl \cdot NaF$,** can be explained in terms of the following arrangement based on O_h^5 (Figure 324c):

F:	(4b)	000; $\frac{1}{2}\frac{1}{2}0$; $\frac{1}{2}0\frac{1}{2}$; $0\frac{1}{2}\frac{1}{2}$	Cl:	(4c)	$\frac{1}{2}\frac{1}{2}\frac{1}{2}$; $00\frac{1}{2}$; $0\frac{1}{2}0$; $\frac{1}{2}00$
S:	(8e)	$\pm(\frac{1}{4}\frac{1}{4}\frac{1}{4})$; $\pm(\frac{1}{4}\frac{3}{4}\frac{3}{4})$; $\pm(\frac{3}{4}\frac{1}{4}\frac{3}{4})$; $\pm(\frac{3}{4}\frac{3}{4}\frac{1}{4})$			
Na:	(24a)	u'00; etc. (see book, p. 303) with $u'=0.226$			
O:	(32a)	$\pm(uuu)$; $\pm(u\bar{u}\bar{u})$; $\pm(\bar{u}\bar{u}u)$; $\pm(\bar{u}u\bar{u})$ and 3 sets of similar points about $0\frac{1}{2}\frac{1}{2}$, $\frac{1}{2}0\frac{1}{2}$ and $\frac{1}{2}\frac{1}{2}0$ (**1930**, 352, p. 110) with $u=0.164$.			

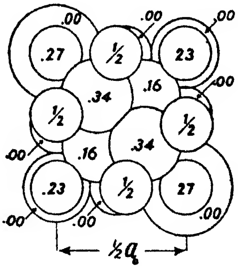


FIG. 324c.—A cube face projection of one eighth of the unit of sulphohalite, $2Na_2SO_4 \cdot NaCl \cdot NaF$. The circles have the radii of their corresponding atoms; in order of decreasing size they refer to Cl^-, O, F^- and Na^+.

(*cm*) The sulfide mineral **tetradymite, Bi_2Te_2S,** has an elongated rhombohedral unit containing one molecule. From photographic data it has been found that atoms are in the following positions:

S: 000 Bi: $\pm(uuu)$ with $u=0.392$ Te: $\pm(vvv)$ with $v=0.788$.

This yields a structure which is a succession of layers of atoms of a kind normal to the three-fold axis. The shortest interatomic distances are: Bi-S=3.05 A, Bi-Te=3.12 A, Te-Te=3.69 A.

Chapter XIXA. Structures of the Silicates

Some of the work of the last three years has been devoted to simple silicates not yet analyzed, some to a revision of previous studies, but for the most part it has been concerned with more complex mineral types whose structures are still imperfectly understood. Most of these are either sheet structures, like the micas, or network groupings, such as the sodalite minerals and the zeolites. The zeolites are of especial interest because of the way they can be dehydrated and can reabsorb water without destruction of their atomic frameworks; approximate arrangements have been deduced for several which aid in understanding how this can occur. Real progress is also being made towards unraveling the crystal structures of the feldspars, one of the few important groups of the silicate minerals for which reasonable atomic arrangements have not been proposed.

A, I. Simple Orthosilicates

(*ak*) A reinvestigation of the structure of **andalusite, Al_2SiO_5,** has led to slightly changed parameters in the X direction for the atoms O(3), O(4) and Al(2) (see Table IX, book, p. 333). The new arrangement, with $x(O, 3)=0.11$, $x(O, 4)=0.25$, $x(Al, 2)=-0.125$, agrees with the earlier one in giving aluminum atoms an oxygen coordination of five.

(*al*) A considerably altered grouping has been proposed for **sillimanite, Al_2SiO_5.** This structure yielding good agreement with the lines observed on a powder photograph differs from the previous one in having regular SiO_4 tetrahedra. Atoms are in the same special positions of V_h^{16} as before (book, pp. 331 and 293) with the new parameters listed in Table II.

(*am*) A structure has been assigned to the **high** temperature cubic form of **carnegieite, $NaAlSiO_4$,** which, if its silicate and aluminate tetrahedra are considered equivalent, is closely related to that of high cristobalite. This arrangement gives calculated intensities agreeing with a powder photograph made at ca 760° C. The atoms in its four-molecule cube are in the following positions of T^4 (book, p. 267):

TABLE I. THE CRYSTAL STRUCTURES OF THE SILICATES

Substance, symmetry and type			a_o	b_o	c_o	*Space group*	*No. mol. per cell*	*References*
Acmite	Mon.	(*at*)	9.71	8.89	5.24	C_{2h}^6	2	**1931**, 464.
$NaFe(SiO_3)_2$				$\beta=74°10'$				
Afwillite	Mon.		11.39	5.47	13.09	C_2^2	4	**1932**, 172.
$3CaO\cdot 2SiO_2\cdot 3H_2O$				$\beta=98°26'$				
Albite	Tri.	(*bm*)	8.14	12.86	7.17	C_i^1	4	**1934**, 262.
$NaAlSi_3O_8$			$\alpha=94°3'$, $\beta=116°29'$, $\gamma=88°9'$					
Amphibole	Mon.	(*t*), (*u*)	9.88	17.70	10.92			**1931**, 139.
(var. Pargasite)				$\beta=$ca 102°				
Analcite	Pseudo-cub.	(*w*), (*bb*)	13.684					**1931**, 158, 242.
$NaAlSi_2O_6\cdot H_2O$								
Andalusite	Ort.	(*g*), (*ak*)						**1931**, 204.
Al_2SiO_5								
Apophyllite	Tet.	(*ah*), (*ba*)	9.00		15.8	D_{4h}^6	2	**1931**, 443.
$KF\cdot Ca_4Si_8O_{20}\cdot 8H_2O$								
Ardennite	Ort.		18.56	5.83	8.72	V_h^{13}	2	**1932**, 175.
$(SiO_4)_5AsO_4Al_3Mn(AlOH)_2Mn_4\cdot 2H_2O$ (?)								
Ashcroftine	Tet.		34.04		17.49		40	**1933**, 195.
$NaK(Ca, Mg, Mn)Al_4Si_5O_{18}\cdot 8H_2O$								
Astrophyllite	Ort.		11.70	5.40	21.10		4	**1934**, 91.
$[Si_2O_7]_2[(Ti, Zr)(OH, F)_2](Fe, Mn)_4(K, Na)_2$								
Axinite	Ort.		12.87	7.15	8.91		2	**1932**, 172.
$MgHCa_2BAl_2(SiO_4)_4$								
Bavenite	Ort.		9.67	11.53	4.95	V_h^1 (?)	1	**1933**, 276.
$9SiO_2\cdot Al_2O_3\cdot BeO\cdot 4CaO\cdot H_2O$								
Bertrandite	Ort.	(*as*)	15.19	8.67	4.53	C_{2v}^{12}	4	**1932**, 232.
$H_2Be_4Si_2O_9$								

Substance, symmetry and type			a_o	b_o	c_o	*Space group*	*No. mol. per cell*	*References*
Braunite $3Mn_2O_3 \cdot MnSiO_3$	Tet.		9.50		18.98	D_{4h}^{20}	8	**1931**, 9.
Cancrinite $3(Na_2Al_2O_4 \cdot 2SiO_2) \cdot 2CaCO_3$	Hex.	(*ab*, (*bl*)	12.72		5.18	C_6^1 (?)	1	**1930**, 457; **1932**, 275; **1933**, 269, 270.
α-Carnegieite $NaAlSiO_4$	Cub.	(*am*)	7.37 at ca 760° C			T^4	4	**1932**, 27.
Chabazite $CaAl_2Si_4O_{12} \cdot 6H_2O$	Hex.	(*bf*)	13.75		14.94	D_{3d}^5	2	**1931**, 488; **1932**, 286; **1933**, 514.
Chlorites	Mon.	(*v*), (*ax*)						**1930**, 423; **1934**, 161.
Cyanite Al_2SiO_5	Tri.	(*h*)						**1931**, 204.
Dickite $Al_2Si_2O_5(OH)_4$	Mon.	(*az*)	5.14	8.94 $\beta = 96°50'$	14.42	C_s^4	4	**1932**, 184.
Edingtonite $Ba_2Al_4Si_6O_{20} \cdot 8H_2O$	Tet. (?)	(*bg*)	9.7		6.6	V_d^3	2	**1933**, 468; **1934**, 108.
Enstatite (var. Bronzite)	Ort.	(*s*), (*au*)	18.16	8.84	5.19	V_h^{15}	16	**1932**, 436.
Epididymite $NaBeSi_3O_7(OH)$	Ort.	(*av*)	12.63	7.32	13.58	V_h^{16}	8	**1934**, 119.
Epidote $(SiO_4)_3Al_2Ca_2(Al,Fe)OH$	Mon.	(*bo*)	16.39	5.63 $\beta = 98°57'$	10.20		4	**1930**, 111d; **1931**, 74; **1932**, 172.
Euclase $HBeAlSiO_5$	Mon.	(*ap*)	4.62	14.24 $\beta = 79°44'$	4.75	C_{2h}^5	4	**1933**, 46.
Eudialyte	Hex.	(*af*)						**1930**, 105a, 193b.
Eulytite $Bi_4Si_3O_{12}$	Cub.	(*ao*)	10.272			T_d^6	4	**1928**, 253a; **1931**, 299.
Feldspars	Mon. and Tri.	(*ac*), (*bm*)						**1929**, 289a, 381; **1931**, 391; **1933**, 467; **1934**, 262.

Fuller's Earth $Al_2O_3 \cdot 4SiO_2 \cdot H_2O$	Hex.		10.20		10.00		4	**1932**, 486.
Garnet	Cub.	(*c*), (*bs*)						**1933**, 182, 521, 522.
Gehlenite (synthetic)	Tet.	(*n*)	7.69		5.10	V_d^3		**1930**, 437, 438.
Haüynite $Na_8Si_6Al_6O_{24}(1\text{-}2, SO_4)$	Cub.	(*aa*), (*bj*)	9.11					**1932**, 23, 26; **1933**, 30; **1934**, 162.
Hemimorphite $Zn_4(OH)_2Si_2O_7 \cdot H_2O$	Ort.	(*ag*), (*ar*)	8.38	10.70	5.11	C_{2v}^{20}	2	**1932**, 231.
Heulandite	Mon.	(*aj*), (*bi*)	7.5438	17.969 $\beta=88°34'$	15.913	C_{2h}^3	1	**1932**, 503; **1933**, 514.
Hornblendes*	Mon.	(*t*)	9.88	17.85 $\beta=$ca 74°	5.443			**1931**, 139, 227; **1934**, 128.
Joaquinite $NaBa(Ti, Fe)_3Si_4O_{15}$	Ort.		9.61	10.45	22.4		4	**1932**, 351.
Kaliophilite $KAlSiO_4$	Hex.	(*aj*)	27.0		8.51		54	**1931**, 28.
Kaolin $Al_2Si_2O_5(OH)_4$	Mon.	(*az*)	5.14	8.90 $\beta=100°12'-101°30'$	14.51	C_s^4	4	**1932**, 183.
Lawsonite $Ca(SiO_3)_2 \cdot (AlO_2H_2)_2$	Ort.		5.87	8.85	13.22	V_h^{17}	4	**1931**, 135a.
Leucophanite $(Ca,Na)_2BeSi_2(O,OH,F)_7$	Ort.	(*n*)	7.38	7.38	9.96		4	**1931**, 493.
Lievrite $CaFe_2^{++}(Fe^{+++}OH)(SiO_4)_2$	Ort.		8.82	13.07	5.86		4	**1932**, 172.

*A Korean hornblende of the composition $(O,OH,F)_2(Ca,Na,K)_{2.8}(Mg,Fe,^{++}Mn,Fe,^{+++}Ti)_5[(Si,Al)_4O_{11}]_2$ has $a_o=9.77$ A, $b_o=17.85$ A, $c_o=5.32$ A, $\beta=73°58'$.

Substance, symmetry and type			a_o	b_o	c_o	*Space group*	*No. mol. per cell*	*References*
Lusakite $H_2O\cdot 4(Fe,Co,Ni,Mg)O\cdot 9(Al,Fe)_2O_3\cdot 8H_2O$	Ort.		7.86	16.62	5.65	V_h^{17}	1	1934, 246.
Meliphanite	Tet.	(*n*)	10.58		9.88		8	1931, 493.
Mesolite $Na_2Ca_2Al_6Si_9O_{30}\cdot 8H_2O$	Mon.	(*be*)	56.7	6.54 $\beta=90°$	18.44	C_2^3	8	1933, 194, 469.
Milarite $HKCa_2Al_2(Si_2O_5)_6$	Hex.		10.46		13.90	D_{6h}^2	2	1930, 111b.
Montmorillonite $H_2O\cdot Al_2O_3\cdot 4SiO_2$	Ort.	(*az*)	5.095	8.83	15.2			1933, 205.
Muscovite $KAl_2(AlSi_3)O_{10}(OH)_2$	Mon.	(*v*), (*aw*)	5.18	9.02 $\beta=95°30'$	20.04	C_{2h}^6	4	1930, 153.
Nacrite $Al_2Si_2O_5(OH)_4$	Mon.	(*az*)	5.16	8.93 $\beta=91°43'$	28.66	C_s^4	8	1933, 160.
Narsarsukite $(Si_4O_{11})(Ti,FeF)Na_2$	Tet.		10.78		7.99	C_{4h}^4	4	1932, 174.
Natrolite $Na_2Al_2Si_3O_{10}\cdot 2H_2O$	Ort.	(*y*), (*bc*)						1931, 489; 1932, 189, 217; 1933, 469, 514.
Nephelite $NaAlSiO_4$	Hex.	(*ad*), (*bp*)						1931, 28.
Noselite $Na_8Al_6Si_6O_{24}\cdot SO_4$	Cub.	(*aa*), (*bj*)	9.03				1	1932, 23, 26; 1934, 162.
Pectolite $NaHCa_2(SiO_3)_3$	Tri.	(*s*), (*bn*)	7.91 $\alpha=90°$,	7.08 $\beta=95°10'$,	7.05 $\gamma=103°0'$		2	1931, 464.
Pollucite $(CsAl,H_4)Si_2O_6$	Cub.		13.66				16	1932, 173.
Prehnite $Ca_2(SiO_3)_3(AlOH)AlO_2H$	Ort.		4.65	5.52	18.53	V_h^7 or C_{2v}^4	2	1931, 135a.

Pyrophyllite $Al_2Si_4O_{10}(OH)_2$	Mon.	(*ay*)	5.14	8.90 $\beta=99°55'$	18.55		4	1934, 96, 200.
Pyrosmalite $Si_3O_7(Mn,Fe)3(Mn,Fe)(OH,Cl)_2$	Hex.		13.44		7.20	D_{2d}^3	4	1931, 135.
Rinkite $(SiO_4)_2[(Ti,Ce)F]Ca_2Na$	Ort.	(*br*)	18.37	5.63	7.42	V_h^{12} or V_h^{16}	4	1933, 153; 1934, 90.
Sanidine $KAlSi_3O_8$	Mon.	(*bm*)	8.45	12.90 $\beta=116°6'$	7.15	C_{2h}^3	4	1934, 262.
Scapolite	Tet.	(*z*), (*bt*)						1931, 228; 1932, 402.
Scolecite $CaAl_2Si_3O_{10}\cdot 3H_2O$	Mon. (?)	(*y*), (*bd*)	18.44	18.90 $\beta=$ca 90°	6.53			1930, 258; 1933, 469, 514.
Sillimanite $Al_2O_3\cdot SiO_2$	Ort.	(*f*), (*al*)	7.43	7.58	5.74	V_h^{16}	4	1931, 204.
Sodalite $Na_4Al_3Si_3O_{12}Cl$	Cub.	(*x*), (*bj*)	8.89				2	1932, 26.
Disodium Calcium Orthosilicate, Na_2CaSiO_4	Cub.	(*l*), (*an*)	7.49			T^4	4	1932, 28, 29.
Spodumene $LiAl(SiO_3)_2$	Mon.	(*r*), (*at*)	9.50	8.30 $\beta=69°40'$	5.24	C_{2h}^6	4	1931, 464.
Talc $Mg_3Si_4O_{10}(OH)_2$	Mon.	(*ay*)	5.26	9.10 $\beta=100°$	18.81	C_{2h}^6	4	1934, 96.
Thaumasite $CaCO_3\cdot CaSO_4\cdot CaSiO_3\cdot 15H_2O$	Hex.		10.90		10.29		2	1933, 6.
Thomsonite $NaCa_2Al_5Si_5O_{20}\cdot 6H_2O$	Ort.	(*bh*)	13.04	13.06	13.22	C_{2v}^{10}	4	1931, 489; 1932, 216; 1933, 469, 514.

Substance, symmetry and type			a_0	b_0	c_0	*Space group*	*No. mol. per cell*	*References*
Ultramarines	Cub.	(*aa*), (*bj*)						1930, 154a.
Vesuvianite	Tet.	(*ah*), (*aq*)	15.63		11.83	D_{4h}^4		1930, 193a; 1931, 465; 1932, 294; 1933, 461.
Wöhlerite $(SiO_4)_2(ZrF,CbO)Ca_2Na$	Mon.	(*bq*)	10.80	10.26 β=109°3′	7.26	C_{2h}^2 or C_2^2	4	1933, 152; 1934, 90.
Wollastonite $CaSiO_3$	Tri.	(*s*), (*bn*)	7.88 α=90°, β=95°16′, γ=103°25′	7.27	7.03		6	1931, 464.
Zoisite $(SiO_4)_3 \cdot Al_2Ca_2(AlOH)$	Mon.		16.21	5.57 β=90°	10.08		4	1930, 111d; 1932, 172, 175.
Zunyite $Al_{13}Si_5O_{20}(OH,F)_{18}Cl$	Cub.	(*aj*), (*bk*)	13.820			T_d^2	4	1933, 348.

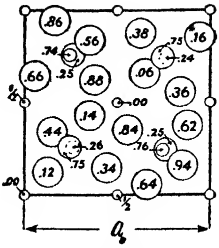


FIG. 325.—A cube face projection of the unit of the structure given to the high temperature (α) modification of carnegieite, $NaAlSiO_4$. In order of decreasing size the circles refer to O, Na, Al and Si atoms.

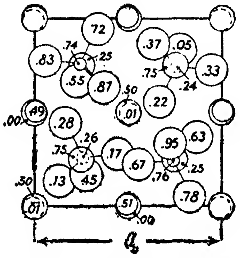


FIG. 326a.—A cube face projection of the atomic arrangement found for Na_2CaSiO_4. Oxygen atoms are shown as the largest circles, Na by slightly smaller ones. Light lines connecting smallest Si with O atoms outline SiO_4 tetrahedra.

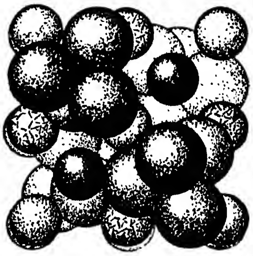


FIG. 326b.—A packing drawing of a. Si atoms cannot be seen; the Ca ions are line-shaded.

TABLE II. PARAMETERS OF THE ATOMS IN SILLIMANITE

Atom	*No. per cell*	*Position*	*x*	*y*	*z*
O(1)	4	(c)	0.15	0.07	0.25
O(2)	4	(c)	−.15	−.07	.25
O(3)	4	(c)	.03	.47	.25
O(4)	8	(d)	−.11	.22	0
Si	4	(c)	.14	−.35	.25
Al(1)	4	(a)	0	0	0
Al(2)	4	(c)	−.14	.35	.25

Al: (4f) uuu; etc. with u=0.258
Si: (4f) with u=0
Na: (4f) with u=0.744
O(1): (4f) with u=0.125
O(2): xyz; etc. with x=0.658, y=0.644, z=0.055.

It will be noticed that this structure (Figure 325) would more closely resemble that of Na_2CaSiO_4 (*an*) if the Si and Al positions were interchanged; such an alternative grouping would give indistinguishable X-ray effects.

(*an*) A further study of the cubic $\mathbf{Na_2CaSiO_4}$ has led to a structure that accounts well for powder photographic data and resembles β-cristobalite and α-carnegieite (*am*). It differs from the previously suggested arrangement (book, p. 338) in an interchange of calcium and half the sodium atoms and in the parameters for oxygen lying in general positions. Its atoms (Figure 326) are in the following special positions of T^4 (book, p. 267):

Si: (4f) uuu; with u=0.258
Ca: (4f) with u=−0.007
Na(1): (4f) with u=0.750
Na(2): (4f) with u=0.500
O(1): (4f) with u=0.134
O(2): xyz; etc. with x=0.555, y=0.667, z=0.222.

(*ao*) The structure proposed for the cubic mineral **eulytite** yields discrete SiO_4 tetrahedra. Its space group is T_d^6 with bismuth atoms in positions:

(16f) uuu; u, $\bar{u}$, $\frac{1}{2}$−u; $\frac{1}{2}$−u, u, $\bar{u}$; $\bar{u}$, $\frac{1}{2}$−u, u;
u+$\frac{1}{4}$, u+$\frac{1}{4}$, u+$\frac{1}{4}$; $\frac{1}{4}$−u, u+$\frac{1}{4}$, $\frac{3}{4}$−u; u+$\frac{1}{4}$, $\frac{3}{4}$−u, $\frac{1}{4}$−u; $\frac{3}{4}$−u, $\frac{1}{4}$−u, u+$\frac{1}{4}$,

and 8 similar points about $\frac{1}{2}\frac{1}{2}\frac{1}{2}$, with u=0.083.

If the other atoms are arranged as follows, a reasonable grouping is obtained that does not conflict with the powder data:

Si: (12k) $\frac{3}{8}0\frac{1}{4}$; $\frac{1}{8}0\frac{3}{4}$; $\frac{3}{4}\frac{7}{8}\frac{1}{2}$; $\frac{3}{4}\frac{1}{8}0$; $0\frac{1}{4}\frac{3}{8}$; $0\frac{3}{4}\frac{1}{8}$; $\frac{7}{8}\frac{1}{2}\frac{3}{4}$; $\frac{5}{8}\frac{1}{2}\frac{1}{4}$; $\frac{1}{4}\frac{3}{8}0$; $\frac{1}{4}\frac{5}{8}\frac{1}{2}$; $\frac{1}{2}\frac{3}{4}\frac{7}{8}$; $\frac{1}{2}\frac{1}{4}\frac{5}{8}$

O: xyz; etc. (**1930**, 352, p. 131) with the parameters x=−0.035, y=0.125, z=0.284. Other values, x=0.055, y=0.11, z=0.284, which cannot be excluded, are thought improbable.

(*ap*) A structure has been proposed for **euclase, $\mathbf{HBeAlSiO_5}$**, which explains spectrometric measurements of the first twelve orders of reflection from the (010) face. This arrangement based on C_{2h}^5, instead of the previously chosen C_{2h}^2, has all its atoms in general positions: (e) $\pm(xyz);\ \pm(x,\ \frac{1}{2}-y,\ z+\frac{1}{2})$ with the parameters of Table III. It is considered that the y parameters are essentially correct but that those along X and Z are only approximate.

TABLE III. PARAMETERS CHOSEN FOR THE ATOMS OF EUCLASE

Atom	*No. per cell*	*x*	*y*	*z*
Be	4	0.50	−0.20	0.02
Al	4	.03	−.06	.25
Si	4	.47	.10	.15
O(1)	4	.22	.05	.39
O(2)	4	.26	−.03	−.17
O(3)	4	.54	.19	.37
O(4)	4	−.28	−.15	.11
OH	4	.22	−.17	.31

(*aq*) A series of spectrometric measurements have been used to give the mineral **vesuvianite** a grouping with four $Ca_{10}Al_4(Mg,\ Fe)_2Si_9O_{34}(OH)_4$ molecules in its tetragonal unit. This arrangement, which somewhat resembles that found for the cubic garnets, has atoms in the following general and special positions of D_{4h}^4:

8(Mg, Fe): (f) $000;\ \frac{1}{2}00;\ 0\frac{1}{2}0;\ 00\frac{1}{2};\ \frac{1}{2}\frac{1}{2}0;\ 0\frac{1}{2}\frac{1}{2};\ \frac{1}{2}0\frac{1}{2};\ \frac{1}{2}\frac{1}{2}\frac{1}{2}$
4 Si(1): (d) $\frac{1}{4}\frac{1}{4}0;\ \frac{3}{4}\frac{3}{4}0;\ \frac{1}{4}\frac{1}{4}\frac{1}{2};\ \frac{3}{4}\frac{3}{4}\frac{1}{2}$ 4 Ca(1): (c) $\frac{1}{4}\frac{1}{4}\frac{1}{4};\ \frac{3}{4}\frac{3}{4}\frac{1}{4};\ \frac{3}{4}\frac{3}{4}\frac{3}{4};\ \frac{1}{4}\frac{1}{4}\frac{3}{4}$
4 Ca(4): (e) $\frac{1}{4}\frac{3}{4}v;\ \frac{1}{4},\ \frac{3}{4},\ \frac{1}{2}-v;\ \frac{3}{4}\frac{1}{4}\bar{v};\ \frac{3}{4},\ \frac{1}{4},\ v+\frac{1}{2}$ with $v=0.13$
8 O(9): (h) $u\bar{u}\frac{1}{4};\ u,\ u+\frac{1}{2},\ \frac{1}{4};\ \frac{1}{2}-u,\ u+\frac{1}{2},\ \frac{1}{4};\ \frac{1}{2}-u,\ \bar{u},\ \frac{1}{4}$
$\bar{u}u\frac{3}{4};\ \bar{u},\ \frac{1}{2}-u,\ \frac{3}{4};\ u+\frac{1}{2},\ \frac{1}{2}-u,\ \frac{3}{4};\ u+\frac{1}{2},\ u,\ \frac{3}{4}$ with $u=0.16$.

The remaining atoms are in the following general positions with parameters as listed in Table IV:

$$\text{(k)}\ \pm(xyz);\ \pm(\bar{y},\ x+\tfrac{1}{2},\ z);\ \pm(\tfrac{1}{2}-x,\ \tfrac{1}{2}-y,\ z);\ \pm(y+\tfrac{1}{2},\ \bar{x},\ z);$$
$$\pm(y+\tfrac{1}{2},\ x+\tfrac{1}{2},\ \tfrac{1}{2}-z);\ \pm(x,\ \tfrac{1}{2}-y,\ \tfrac{1}{2}-z);\ \pm(\bar{y},\ \bar{x},\ \tfrac{1}{2}-z);\ \pm(\tfrac{1}{2}-x,\ y,\ \tfrac{1}{2}-z).$$

The coordinates used in this description are derived from those of **1930**, 352, p. 91 by transferring the origin to such a point as $(-\frac{3}{4},\ -\frac{1}{4},\ \frac{1}{4})$.

It is uncertain how closely this structure describes the atomic arrangement that prevails in vesuvianite crystals. The chosen chemical formula differs from that previously given to the mineral and subsequent studies of the available chemical analyses are said to favor formulas departing appreciably from $Ca_{10}Al_4\ (Mg,\ Fe)_2Si_9O_{34}(OH)_4$. One of these (**1932**, 294) is $X_{19}Y_{13}Si_{18}(O,\ OH,\ F)_{76}$ where X=Ca(Na, etc.) and Y=(Al, Fe, Mg, etc.); another (**1933**, 461) is $Ca_8Al_4(Si,\ Al)_9\ (Fe,\ Mg,\ etc.)_4(O,\ OH,\ F)_{38}$.

TABLE IV. PARAMETERS FOR ATOMS OF VESUVIANITE LYING IN GENERAL POSITIONS

Atom	*No. per cell*	*x*	*y*	*z*
Si(2)	16	0.19	0.05	0.87
Si(3)	16	.09	−.17	.37
Ca(2)	16	.19	.05	.36
Ca(3)	16	.09	−.17	.88
Al	16	.11	.11	.13
O(1)	16	.22	.17	.08
O(2)	16	.13	.16	.28
O(3)	16	.06	.22	.08
O(4)	16	.07	.13	.48
O(5)	16	.17	.01	.18
O(6)	16	.01	.06	.17
O(7)	16	−.05	.18	.32
O(8)	16	.10	−.08	.07
OH	16	.13	−.25	.06

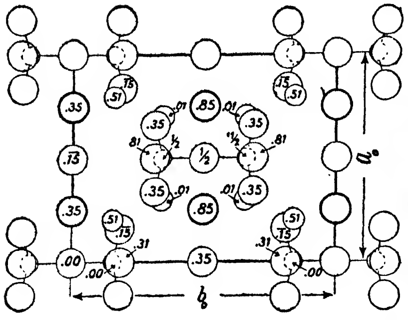
A, II. Complex Silicate Groups

(*ar*) The structure found for **hemimorphite, $H_2Zn_2SiO_5$,** indicates that it is a pyrosilicate with a formula best written as $Zn_4(OH)_2Si_2O_7 \cdot H_2O$. Atoms are in the following positions of C_{2v}^{20}:

2 O(1): (a) $00u; \frac{1}{2}, \frac{1}{2}, u+\frac{1}{2}$ with $u=0$
2 H_2O: (b) $\frac{1}{2}0u; 0, \frac{1}{2}, u+\frac{1}{2}$ with $u=-0.150$
4 OH: (c) $u0v; \bar{u}0v; u+\frac{1}{2}, \frac{1}{2}, v+\frac{1}{2}; \frac{1}{2}-u, \frac{1}{2}, v+\frac{1}{2}$ with $u=0.75$, $v=0.350$
4 O(3): (d) $0uv; 0\bar{u}v; \frac{1}{2}, u+\frac{1}{2}, v+\frac{1}{2}; \frac{1}{2}, \frac{1}{2}-u, v+\frac{1}{2}$ with $u=0.187$, $v=0.305$
4 Si: (d) $0u'v'$; etc. with $u'=0.160$, $v'=0$
8 Zn: (e) $xyz; \bar{x}\bar{y}z; x\bar{y}z; \bar{x}yz$, and four similar points about $\frac{1}{2}\frac{1}{2}\frac{1}{2}$ (1930, 352, p. 56) with $x=0.300$, $y=0.342$, $z=0.010$.
8 O(2): (e) $x'y'z'$; etc. with $x'=0.161$, $y'=0.187$, $z'=0.850$.

In this arrangement a zinc atom is surrounded by three oxygen atoms and one OH group (Figure 327); the water molecules, bounded by OH groups and oxygen atoms lie loosely in big holes that exist in the structure (minimum H_2O to OH or O = ca 3.3 A).

(*as*) An arrangement has been described for the mineral **bertrandite**, $Be_2(BeOH)_2SiO_3SiO_4$, using spectrometric and photographic data. Based on a hexagonal close packing of oxygen atoms it is said to be intermediate between a silicate chain structure and one having discrete silicate groups. Half the silicon atoms are centers of isolated SiO_4 tetrahedra; the other half form parts of tetrahedra which are linked together in endless SiO_3 chains such as those of diopside. Atoms are placed in special and general positions of C_{2v}^{12}:



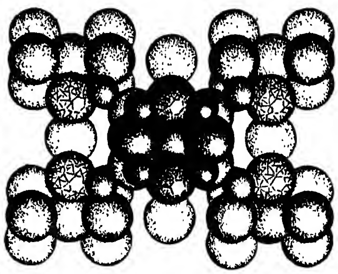


Fig. 327*a*.—(*left*) The structure assigned to hemimorphite, $H_2Zn_2SiO_5$, as projected upon the c-face of its orthorhombic unit. The largest circles represent O atoms, H_2O groups and (OH) radicals. The silicate O atoms are joined by light lines with Si (the smallest circles) to form Si_2O_7 groups; the heavily ringed circles are (OH).

Fig. 327*b*.—(*right*) A packing drawing of *a*. The (OH) radicals are line-shaded; the Si atoms cannot be seen.

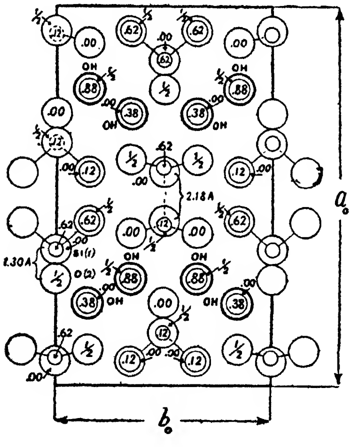


Fig. 328.—The structure proposed for bertrandite, $Be_2(BeOH)_2Si_2O_7$, as projected on the c-face of its orthorhombic unit. The smallest circles are Si, the largest are O atoms [or (OH) if heavily ringed].

Table V. Parameters of the Atoms in Bertrandite

Atom	*No. per cell*	*Position*	*x*	*y*	*z*
Be(1)	8	(b)	0.215	0.155	0.375
Be(2)	8	(b)	.435	.155	.625
Si(1)	4	(a)	.074	0	.625
Si(2)	4	(a)	.360	0	.625
OH	8	(b)	.215	.155	0
O(1)	4	(a)	.065	0	0
O(2)	4	(a)	.283	0	.50
O(3)	4	(a)	.360	0	0
O(4)	8	(b)	.095	.155	.50
O(5)	8	(b)	.435	.155	.50

(a) $u0v;\ \bar{u}, 0, v+\frac{1}{2};\ u+\frac{1}{2}, \frac{1}{2}, v;\ \frac{1}{2}-u, \frac{1}{2}, v+\frac{1}{2}$
(b) $xyz;\ \bar{x}, \bar{y}, z+\frac{1}{2};\ x\bar{y}z;\ \bar{x}, y, z+\frac{1}{2}$ and four similar points about $\frac{1}{2}\frac{1}{2}0$.

The atomic parameters are reproduced in Table V.

As can be seen from Figure 328 this grouping yields several improbable interatomic distances. Atoms Be(2) and O(5) are only 0.57 A apart. Both kinds of silicate groups are distorted. Thus Si(2)-O(2) is 1.30 A while the distance from Si(1) to one of its four surrounding oxygen atoms is 2.18 A.

B. Silicate Chain Structures

(*at*) The structure found for **acmite, $NaFe(SiO_3)_2$,** is identical with that of diopside (*r*) both in cell dimensions and in atomic parameters, with sodium in place of calcium and ferric iron replacing magnesium.

Spodumene, $LiAl(SiO_3)_2$, has the same arrangement but in a cell of appreciably different size and shape. The atomic parameters, with lithium and aluminum in place of calcium and magnesium, have been given approximate values close to those for diopside (see Table VI).

TABLE VI. PARAMETERS OF THE ATOMS IN SPODUMENE

Atom	*No. per cell*	*Position*	*x*	*y*	*z*
Li	4	(e)	0	−0.31	0.25
Al	4	(e)	0	.09	.25
Si	8	(f)	0.21	.41	.25
O(1)	8	(f)	.39	.41	.14
O(2)	8	(f)	.13	.25	.32
O(3)	8	(f)	.14	.49	0

(*au*) Photographic spectral data have been used to assign to a **bronzite, (Fe, Mg)SiO_3,** parameters that agree well with those previously found for enstatite (book, p. 344).

(*av*) A structure for **epididymite, $HNaBeSi_3O_8$,** has been deduced from spectrometric measurements. It places atoms in special and general positions of V_h^{16} with the parameters listed in Table VII:

(a) $000;\ 00\frac{1}{2};\ \frac{1}{2}\frac{1}{2}0;\ \frac{1}{2}\frac{1}{2}\frac{1}{2}$
(b) $0\frac{1}{2}0;\ 0\frac{1}{2}\frac{1}{2};\ \frac{1}{2}00;\ \frac{1}{2}0\frac{1}{2}$
(c) $\pm(uv\frac{1}{4});\ \pm(u+\frac{1}{2}, \frac{1}{2}-v, \frac{1}{4})$
(d) $\pm(xyz);\ \pm(x+\frac{1}{2}, \frac{1}{2}-y, \frac{1}{2}-z);$
$\pm(\bar{x}, \bar{y}, z+\frac{1}{2});\ \pm(x+\frac{1}{2}, \frac{1}{2}-y, z).$

The axes of this description differ from those used for chrysoberyl (book, p. 293) by an interchange of a and b.

This structure must be revised since some of its interatomic distances are impossible; for example Be-Si(1)=0.54 A, Be-O(3)=0.72 A, Si(1)-O(3)=1.13 A (see Table VII).

TABLE VII. PARAMETERS OF THE ATOMS IN EPIDIDYMITE

Atom	*No. per cell*	*Position*	*x*	*y*	*z*
Na(1)	4	(a)	0	0	0
Na(2)	4	(b)	0	½	0
Be	8	(d)	0.035	0.250	0.052
Si(1)	8	(d)	.065	.200	.060
Si(2)	8	(d)	.435	.200	−.060
Si(3)	8	(d)	.335	.250	.000
OH(1)	4	(c)	−.155	.150	¼
OH(2)	4	(c)	.041	.250	¼
O(1)	8	(d)	.040	.000	.145
O(2)	8	(d)	.040	.500	.145
O(3)	8	(d)	.000	.250	.010
O(4)	8	(d)	.167	.000	−.040
O(5)	8	(d)	.167	.500	−.040
O(6)	8	(d)	.182	.250	.130
O(7)	8	(d)	.318	.250	−.130

C. Two-dimensional Silicate Nets

(*aw*) The atomic arrangement which has been given to the mica **muscovite, $KAl_2(AlSi_3)O_{10}(OH)_2$,** through a study of photographic and spectrometric intensities is based on C_{2h}^6 (book, p. 343). Approximate parameters of its atoms, all of which except potassium are in general positions, are listed in Table VIII. The central atoms of one quarter of the tetrahedra linked together to produce sheets are aluminum instead of silicon.

(*ax*) Six **chlorites** with the approximate composition $Al_2Mg_5Si_3O_{10}(OH)_8$ possess four-molecule monoclinic units having dimensions within the limits $a_0 = 5.304–5.352$ A, $b_0 = 9.187–9.270$ A, $c_0 = 28.306–28.582$ A, $\beta = 97°9'$. Their space group is considered to be either C_{2h}^3 or C_{2h}^6. Adopting earlier suggestions that the brittle micas are built up of alternate mica- and brucite-like layers, structures have been assumed and compared with intensities on powder photographs. A grouping with the symmetry of C_{2h}^6 has been preferred but it is obvious that at least until the arrangements based on C_{2h}^3 are definitely eliminated the chlorite structure has not been established.

(*ay*) Taking the data from powder photographs practically identical structures have been proposed for a **talc**, $Mg_3Si_4O_{10}(OH)_2$, and for **pyrophyllite**, $Al_2Si_4O_{10}(OH)_2$. The distribution within layers is that previously suggested but the layers are said to be stacked according to the requirements of C_{2h}^6, not of C_{2h}^3. Parameters have been proposed but additional confirmation and a more precise description of the arrangement is desirable.

(*az*) The **clay minerals** with their pronounced micaceous cleavage should have silicon-oxygen tetrahedra united to form sheets. Structures built up of such sheets have been proposed for kaolin, dickite and nacrite,

TABLE VIII. PARAMETERS OF THE ATOMS IN MUSCOVITE

Atom	*No. per cell*	*Position*	*x*	*y*	*z*
OH	8	(f)	0.062	0.083	0.055
O(1)	8	(f)	.062	.417	.055
O(2)	8	(f)	.062	.250	.055
O(3)	8	(f)	.478	.083	.164
O(4)	8	(f)	.228	.166	.164
O(5)	8	(f)	.228	.332	.164
(Si+Al)(1)	8	(f)	.033	.417	.135
(Si+Al)(2)	8	(f)	.033	.250	.135
Al	8	(f)	.250	.083	0
K	4	(e)	0	.083	.250

each with the composition $Al_2Si_2O_5(OH)_4$. These groupings, based of necessity on powder photographic data and not conclusively proved, are similar; they differ mainly in the orientation of their silicate layers. Each is developed from C_s^4 with all atoms in general positions: (a) xyz; $x+\frac{1}{2}$, $y+\frac{1}{2}$, z; x, $\bar{y}$, $z+\frac{1}{2}$; $x+\frac{1}{2}$, $\frac{1}{2}-y$, $z+\frac{1}{2}$. Kaolin and dickite have four-molecule cells; the unit of nacrite is twice as big. The atomic parameters are listed in Tables IX and X. Other arrangements for both kaolin and dickite are in almost equally good agreement with the data. It is suggested that some samples may have these alternative groupings—or one which combines both. The mineral anauxite resembles kaolin but contains a greater amount of silicon. If this silicon replaces aluminum, as has been proposed, it would have a hitherto unknown six-fold coordination.

Some measurements have indicated that the substance called montmorillonite has an orthorhombic cell similar in size and shape to the monoclinic cell of kaolin (**1933**, 205).

(*ba*) **Apophyllite** is a mineral which is sometimes considered a zeolite, sometimes more nearly a mica. Some water can be driven from it without

TABLE IX. ATOMIC PARAMETERS FOR KAOLIN AND DICKITE

		Kaolin			*Dickite*	
Atom	*x*	*y*	*z*	*x*	*y*	*z*
Al(1)	0.25	−0.17	0	0.25	0.41	0
Al(2)	.25	.17	0	.25	.08	0
Si(1)	.01	.50	0.19	.14	.25	0.19
Si(2)	.01	.17	.19	−.36	.08	.19
O(1)	−.05	.50	.08	.11	.25	.08
O(2)	−.05	.17	.08	−.39	.08	.08
O(3)	.03	.33	.23	.16	.42	.23
O(4)	.28	−.41	.23	.41	.17	.23
O(5)	.28	.08	.23	−.09	.17	.23
OH(1)	−.05	−.17	.08	−.39	.42	.08
OH(2)	−.05	0	.42	−.11	.25	.42
OH(3)	−.45	.17	.42	.39	.08	.42
OH(4)	.05	.33	.42	.39	.42	.42

TABLE X. ATOMIC PARAMETERS FOR NACRITE

Atom	*x*	*y*	*z*	*Atom*	*x*	*y*	*z*
Al(1)	0.75	0.33	0	O(6)	−0.08	0.50	0.29
Al(2)	.75	0	0	O(7)	−.08	.17	.29
Al(3)	.08	0	0.25	O(8)	.44	−.17	.36
Al(4)	.08	−.33	.25	O(9)	.19	−.42	.36
Si(1)	.43	.33	.09	O(10)	.19	.08	.36
Si(2)	.43	0	.09	OH(1)	−.08	.17	.04
Si(3)	.43	−.33	.34	OH(2)	−.26	−.33	.21
Si(4)	.43	0	.34	OH(3)	−.26	0	.21
O(1)	−.08	.50	.04	OH(4)	−.26	.33	.21
O(2)	−.08	−.17	.04	OH(5)	−.08	−.17	.29
O(3)	.44	.17	.11	OH(6)	.08	−.33	.46
O(4)	.19	.42	.11	OH(7)	.08	0	.46
O(5)	.19	−.08	.11	OH(8)	.08	.33	.46

loss of structure but this is more difficult to do than with the true zeolites and the lost water is not readily reabsorbed. The arrangement given it from a study of rotation photographs and some spectrometric measurements is mica-like and contains hydroxyl groups rather than H_2O molecules. Its two molecules of composition $Ca_4Si_8O_{20}\cdot 8H_2O\cdot KF$ are in the following positions (1930, 352, p. 92) of D_{4h}^6:

2 F: (a) $000;\ \frac{1}{2}\frac{1}{2}\frac{1}{2}$ 2 K: (b) $00\frac{1}{2};\ \frac{1}{2}\frac{1}{2}0$
8 Ca: (h) $uv0;\ v\bar{u}0;\ v+\frac{1}{2}, u+\frac{1}{2}, \frac{1}{2};\ u+\frac{1}{2}, \frac{1}{2}-v, \frac{1}{2};\ \bar{u}\bar{v}0;\ \bar{v}u0;\ \frac{1}{2}-v, \frac{1}{2}-u, \frac{1}{2};$
$\frac{1}{2}-u, v+\frac{1}{2}, \frac{1}{2}$ with $u=0.120$, $v=0.243$
8 O(1): (g) $u, u+\frac{1}{2}, \frac{1}{4};\ u+\frac{1}{2}, \bar{u}, \frac{1}{4};\ \bar{u}, \frac{1}{2}-u, \frac{1}{4};\ \frac{1}{2}-u, u, \frac{1}{4};\ u, u+\frac{1}{2}, \frac{3}{4};$
$u+\frac{1}{2}, \bar{u}, \frac{3}{4};\ \bar{u}, \frac{1}{2}-u, \frac{3}{4};\ \frac{1}{2}-u, u, \frac{3}{4}$ with $u=0.362$
16 O(2): (i) $\pm(xyz);\ \pm(y\bar{x}z);\ \pm(\bar{x}\bar{y}z);\ \pm(\bar{y}xz);\ \pm(\frac{1}{2}-x, y+\frac{1}{2}, z+\frac{1}{2});$
$\pm(\frac{1}{2}-y, \frac{1}{2}-x, z+\frac{1}{2});\ \pm(x+\frac{1}{2}, \frac{1}{2}-y, z+\frac{1}{2});\ \pm(y+\frac{1}{2}, x+\frac{1}{2}, z+\frac{1}{2})$
with $x=0.089$, $y=0.184$, $z=0.217$
16 O(3): (i) $x_1y_1z_1$; etc. with $x_1=0.287$, $y_1=0.117$, $z_1=0.094$
16 O(4): (i) $x_2y_2z_2$; etc. with $x_2=0.237$, $y_2=0.445$, $z_2=0.094$
16 Si: (i) $x'y'z'$; etc. with $x'=0.237$, $y'=0.091$, $z'=0.188$.

D. Three-dimensional Silicate Nets

The zeolites have the surprising property of being able to lose and to reabsorb water without destruction of their underlying atomic arrangements. Previous studies [see (*w*)] of analcite, $NaAlSi_2O_6\cdot H_2O$, have indicated that this zeolite consists of a three-dimensional network of interlocking AlO_4 and SiO_4 tetrahedra with metal atoms and water molecules occupying holes in the framework thus formed. Measurements on several other zeolites have now yielded similar results.

(*bb*) A recent investigation of **analcite** indicates that it is not cubic but tetragonal with D_{4h}^{20} as the correct space group. It has also been shown that dehydration does not seriously alter the observed powder pattern of this zeolite.

(*bc*) The structure found for **natrolite** from photographic spectral data has the symmetry of C_{2v}^{19} and contains eight molecules of the composition $Na_2Al_2Si_3O_{10}\cdot 2H_2O$. All atoms except one set of silicon are in general positions (**1930**, 352, p. 55):

(b) $xyz;\ \bar{x}\bar{y}z;\ x+\frac{1}{4},\ \frac{1}{4}-y,\ z+\frac{1}{4};\ \frac{1}{4}-x,\ y+\frac{1}{4},\ z+\frac{1}{4}$ and three sets of similar points about $\frac{1}{2}\frac{1}{2}0,\ \frac{1}{2}0\frac{1}{2},\ 0\frac{1}{2}\frac{1}{2}$.

The parameters of these atoms are listed in Table XI. Si(1) atoms are in special positions (a) 00u; etc. with u=0; i.e. at the points 000; $\frac{1}{2}\frac{1}{2}0$; $\frac{1}{2}0\frac{1}{2}$; $0\frac{1}{2}\frac{1}{2}$; $\frac{1}{4}\frac{1}{4}\frac{1}{4}$; $\frac{3}{4}\frac{3}{4}\frac{1}{4}$; $\frac{3}{4}\frac{1}{4}\frac{3}{4}$; $\frac{1}{4}\frac{3}{4}\frac{3}{4}$. The nature of the tetrahedral network and the positions occupied by water molecules can be seen from Figure 329.

Besides closely agreeing determinations of cell dimensions on natural natrolites from several sources, cell data exist on four synthetic compounds of this type (Table XII).

TABLE XI. PARAMETERS FOR ATOMS OF NATROLITE LYING IN GENERAL POSITIONS

Atom	*No. per cell*	*x*	*y*	*z*
Na	16	0.222	0.028	0.625
Al	16	.036	.089	.625
Si(2)	16	.153	.208	.625
O(1)	16	.069	.180	.625
O(2)	16	.014	.067	.875
O(3)	16	.183	.236	.375
O(4)	16	.097	.042	.500
O(5)	16	.208	.153	.750
H_2O	16	.069	.180	.125

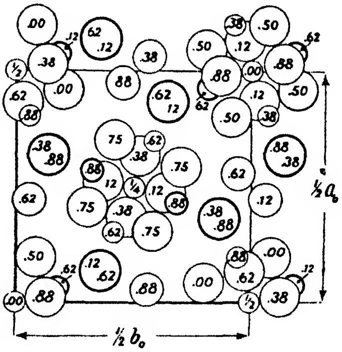


FIG. 329.—A projection upon its c-face of one eighth of the unit of natrolite, $Na_2Al_2Si_3O_{10}\cdot 2H_2O$. The small light circles are Si, the ringed small circles are Al atoms. Na atoms are shown by circles of intermediate size; the largest ringed circles are H_2O molecules.

TABLE XII. CELL DIMENSIONS ON SUBSTITUTED NATROLITES

Compound	a_0	b_0	c_0
$Na_2Al_2Si_3O_{10}\cdot 2H_2O$	18.3	18.6	6.57
$Li_2Al_2Si_3O_{10}\cdot 2H_2O$	18.0	18.6	6.5
$Ag_2Al_2Si_3O_{10}\cdot 2H_2O$	18.6	18.9	6.6
$(NH_4)_2Al_2Si_3O_{10}$ anhydrous	17.9	18.4	6.6

(*bd*) The X-ray patterns of **scolecite**, $CaAl_2Si_3O_{10}\cdot 3H_2O$, are indistinguishable from those of natrolite so that it must have a unit of practically the same size and shape. Earlier it was suggested (**1930**, 258) that Ca+3 H_2O of scolecite replace 2 Na+2 H_2O of natrolite. A recent study proposes instead that Ca atoms in the former occupy half the Na positions in natrolite leaving the other half vacant and that the eight new H_2O molecules go into half the 16-fold unoccupied holes in the natrolite structure with the approximate parameters $x=0.22$, $y=0.028$, $z=0.125$. No data are available for distinguishing between these possibilities.

(*be*) **Mesolite,** $Na_2Ca_2Al_6Si_9O_{30}\cdot 8H_2O$, is another zeolite which gives a pattern nearly identical with that of natrolite. The large cell of Table I is indicated by certain faint lines seen on some rotation photographs.

(*bf*) Data from spectral photographs have been used to assign an atomic arrangement to the rhombohedral zeolite **chabazite.** The atoms of the two $CaAl_2Si_4O_{12}\cdot 6H_2O$ molecules are in the following positions of D_{3d}^5:

2 Ca: (c) $\pm(uuu)$ with $u=0.17$
6 O(1): (f) $\pm(u\bar{u}0);\ \pm(\bar{u}0u);\ \pm(0u\bar{u})$ with $u=0.34$
6 O(2): (g) $\pm(u\bar{u}\tfrac{1}{2});\ \pm(\bar{u}\tfrac{1}{2}u);\ \pm(\tfrac{1}{2}u\bar{u})$ with $u=0.14$
6 O(3): (h) $\pm(uuv);\ \pm(uvu);\ \pm(vuu)$ with $u=0.35$, $v=-0.02$
6 O(4): (h) $u'u'v'$ with $u'=0.13$, $v'=0.50$
$H_2O(1)$: (h) $u_1u_1v_1$ with $u_1=0.31$, $v_1=0.70$
$H_2O(2)$: (h) $u_2u_2v_2$ with $u_2=0.14$, $v_2=-0.08$
(Si+Al): (i) $\pm(xyz);\ \pm(yzx);\ \pm(zxy);\ \pm(yxz);\ \pm(xzy);\ \pm(zyx)$

with $x=0.23$, $y=0.44$, $z=-0.01$.

X-ray studies have been made of the dehydration of chabazite. It has also been shown that mercury can replace the water in this zeolite without destroying its diffraction pattern; by one investigator (**1932**, 286) this has been taken to mean that the water molecules do not occupy definite positions within the chabazite structure.

(*bg*) Another zeolite to which an atomic arrangement has been assigned is **edingtonite,** $Ba_2Al_4Si_6O_{20}\cdot 8H_2O$. There is some uncertainty as to the true symmetry of this mineral. Samples of Swedish origin have been found to be orthorhombic with $a_o=9.56$ A, $b_o=9.68$ A, $c_o=6.53$ A; their space group has been reported as V^3. Material from Old Kilpatrick, Scotland with the cell dimensions of Table I is said to be completely tetragonal.

The Laue photographs of edingtonite from Böhlet, Sweden are apparently tetragonal. Proceeding on the assumption that its atomic arrangement does not depart significantly from this higher symmetry, photographic spectral data have been used to place its two molecules in the following special and general positions of V_d^3 (**1930**, 352, p. 74):

Ba: (c) $0\frac{1}{2}u$; $\frac{1}{2}0\bar{u}$ with $u=0.375$ (Al+Si)(1): (a) 000; $\frac{1}{2}\frac{1}{2}0$

$H_2O(1)$: (e) $u, \frac{1}{2}-u, v$; $\frac{1}{2}-u, \bar{u}, \bar{v}$; $\bar{u}, u+\frac{1}{2}, v$; $u+\frac{1}{2}, u, \bar{v}$ with $u=0.333$, $v=0.875$

$H_2O(2)$: (e) $u', \frac{1}{2}-u', v'$ with $u'=0.103$, $v'=0$

O(1): (e) $u_1, \frac{1}{2}-u_1, v_1$ with $u_1=0.333$, $v_1=0.375$

O(2): (f) xyz; $y\bar{x}\bar{z}$; $\bar{x}\bar{y}z$; $\bar{y}x\bar{z}$; $\frac{1}{2}-x, y+\frac{1}{2}, \bar{z}$; $\frac{1}{2}-y, \frac{1}{2}-x, z$; $x+\frac{1}{2}, \frac{1}{2}-y, \bar{z}$; $y+\frac{1}{2}, x+\frac{1}{2}, z$ with $x=0.055$, $y=0.194$, $z=0.472$

O(3): (f) $x_1y_1z_1$ with $x_1=0.128$, $y_1=0.047$, $z_1=0.139$

(Al+Si)(2): (f) $x'y'z'$ with $x'=0.186$, $y'=0.103$, $z'=0.375$.

The similarity between the tetrahedral strings in this mineral and in other zeolites can be seen by comparing Figure 330 with Figure 329 for natrolite. In this edingtonite arrangement four H_2O molecules are coordinated about each barium atom. The positions chosen for water are considered most probable but because of the heavy barium the available X-ray data cannot locate them uniquely.

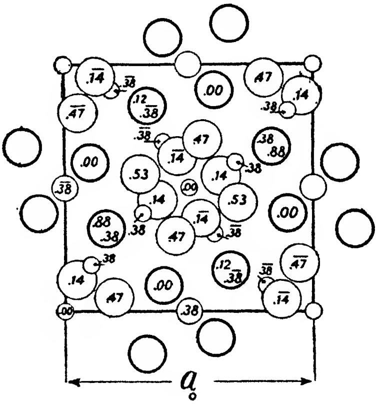


FIG. 330.—A basal projection of the tetragonal structure given to edingtonite, $Ba_2Al_4Si_6O_{20} \cdot 8H_2O$. Al and Si atoms, which are not separately determined, are the smallest circles; intermediate circles are Ba. Molecules of H_2O are heavily ringed.

(*bh*) The true unit prism of **thomsonite**, $NaCa_2Al_5Si_5O_{20} \cdot 6H_2O$, contains four molecules (Table I). There is, however, an approximate halving along the c direction that suggests a two-molecule pseudo-unit. A structure based on this pseudo-cell with its atoms in the following positions of V_h^7 is thought to be approximately correct.

Ca: (c) $\frac{1}{2}0\frac{1}{2}$; $0\frac{1}{2}\frac{1}{2}$

(2 Ca+2 Na): (h) $\pm(u0v)$; $\pm(\frac{1}{2}-u, \frac{1}{2}, v)$ with $u=0.069$, $v=0.25$

(2 Si+2 Al): (g) $\pm(\frac{1}{4}\frac{1}{4}u)$; $\pm(\frac{3}{4}\frac{1}{4}\bar{u})$ with $u=0.875$

$H_2O(1)$: (e) $\pm(0u0)$; $\pm(\frac{1}{2}, \frac{1}{2}-u, 0)$ with $u=0.139$

$H_2O(2)$: (h) u_10v_1 with $u_1=0.403$, $v_1=0.75$

$H_2O(3)$: (h) u_20v_2 with $u_2=0.111$, $v_2=0.75$

O(1): (f) $\pm(\frac{1}{2}u\frac{1}{2})$; $\pm(0, u+\frac{1}{2}, \frac{1}{2})$ with $u=0.361$

O(2): (h) $u'0v'$ with $u'=0.402$, $v'=0.25$.

TABLE XIII. PARAMETERS FOR ATOMS OF THOMSONITE LYING IN GENERAL POSITIONS

Atom	*No. per cell*	*x*	*y*	*z*
O(3)	8	0.167	0.194	0.75
O(4)	8	.180	.119	.375
O(5)	8	.305	.139	0
O(6)	8	.375	.194	.375
(Si+Al)(2)	8	.125	.194	.500
(Al+Si)(3)	8	.305	.125	.250

The rest of the atoms are in general positions: (i) ±(xyz); ±(x$\bar{y}$z); ±(½−x, ½−y, z); ±(x+½, ½−y, $\bar{z}$), with the parameters of Table XIII. It has been suggested that this simplified structure departs from the true one mainly in the distribution of Al and Si atoms within the positions assigned to them as centers of oxygen tetrahedra. The existing data are inadequate to show whether this is the case.

The axes of this description (abc) are connected with those of **1930**, 352, p. 61 (X′Y′Z′) by the relations: a=Z′, b=X′, c=Y′.

(*bi*) X-ray patterns have been made of partially dehydrated **heulandite** and of the β-heulandite obtained by dehydrating above 210° C. The former gives a heulandite-like pattern and takes up water reversibly. The β-form cannot be reversed. Digestion of heulandite in HCl results in a silica which, though pseudomorphic after the original crystal, yields an amorphous X-ray pattern.

(*bj*) Other minerals which have been found to have three-dimensional linked SiO_4 and AlO_4 tetrahedral networks are members of the **sodalite** group.

A structure for sodalite itself, $Na_4Al_3Si_3O_{12}Cl$, has already been proposed [(*x*) book, p. 352]. This was developed from the space group T_d^4. Similar arrangements have been suggested for haüynite and noselite. Writing the formula for haüynite as essentially $Na_4Al_3Si_3O_{12}SO_4$ with some substitution of calcium for sodium, the necessary atomic positions, already listed for sodalite, [(*x*) book, p. 352], are:

S: (2a) 000; ½½½ Si: (6f) 0½¼; etc. Al: (6g) ½0¼, etc.
Na: (8a) uuu with u=0.222 O(1): (8a) u′u′u′ with u′=−0.10
O(2): (i) xyz with x=0.136, y=0.475, z=0.147.

The coordinates for noselite are nearly identical, the assumption being made that only some of the sulfate positions centering about 000 and ½½½ are occupied. For Na, u=0.217; for O(1), u′=−0.100; for O(2), x=0.136, y=0.475, z=0.147.

A debate over the true formula of haüynite has led to another, but closely related, structure based on T_d^1. Considering this mineral to be a solid solution of the composition $(Na, Ca)_{4-8}Al_6Si_6O_{24}\cdot(SO_4)_{1-2}$, sodalite

TABLE XIV. THE T_d^1 STRUCTURES FOR SODALITE AND NOSELITE

Arrangement		Sodalite		Noselite	
		Atom	Parameters	Atom	Parameters
(1a)	000	Cl	—	S	—
(1b)	$\frac{1}{2}\frac{1}{2}\frac{1}{2}$	Cl	—	—	—
(12f)	$u0\frac{1}{2}$; etc.	(6Al+6Si)	$u=0.25$	(6Al+6Si)	$u=0.25$
(4a)	uuu; etc.	Na(1)	$u=0.175$	Na(1)	$u=0.150$
(4a)	$u'u'u'$; etc.	Na(2)	$u'=0.675$	Na(2)	$u'=0.750$
(4a)	$u_1u_1u_1$; etc.	—	—	O(1)	$u_1=0.897$
(12g)	uuv; etc.	O(1)	$u=0.147$	O(2)	$u=0.144$
			$v=0.445$		$v=0.473$
(12g)	$u'u'v'$; etc.	O(2)	$u'=0.660$	O(3)	$u'=0.645$
			$v'=-0.056$		$v'=-0.028$

(4a): $uuu;\ u\bar{u}\bar{u};\ \bar{u}u\bar{u};\ \bar{u}\bar{u}u$

(12f): $u0\frac{1}{2};\ \bar{u}0\frac{1}{2};\ u\frac{1}{2}0;\ \bar{u}\frac{1}{2}0;\ \frac{1}{2}u0;\ \frac{1}{2}\bar{u}0;\ 0u\frac{1}{2};\ 0\bar{u}\frac{1}{2};\ 0\frac{1}{2}u;\ 0\frac{1}{2}\bar{u};\ \frac{1}{2}0u;\ \frac{1}{2}0\bar{u}$

(12g): $uuv;\ u\bar{u}\bar{v};\ \bar{u}u\bar{v};\ \bar{u}\bar{u}v;\ vuu;\ \bar{v}u\bar{u};\ \bar{v}\bar{u}u;\ v\bar{u}\bar{u};\ uvu;\ \bar{u}\bar{v}u;\ u\bar{v}\bar{u};\ \bar{u}v\bar{u}$.

and noselite have been assigned the groupings of Table XIV. Upon this basis some but not all cells of haüynite would contain SO_4 groups in approximately the positions (1b) and (4a) [for O(1)] of noselite; Ca would replace Na(1) or Na(2). A convincing choice between these alternative arrangements cannot be made from the existing X-ray data.

It has been found that the two minerals ittnerite and skolopsite (**1934**, 162) give weak haüynite patterns and presumably are alteration products.

None of these more recent studies of substances related to the ultramarines (*aa*) gives support to the suggestion earlier advanced that their alkali atoms are "wandering" without fixed positions in the structure.

(*bk*) The following structure, which gives qualitative agreement with the data from two oscillation photographs, has been proposed for **zunyite**, $Al_{13}Si_5O_{20}(OH, F)_{18}Cl$. Based on T_d^2 it places four molecules within the unit cube. Atoms are in points having the coordinates listed below and in three similar sets of points (**1930**, 352, p. 128) about $\frac{1}{2}\frac{1}{2}0;\ \frac{1}{2}0\frac{1}{2};\ 0\frac{1}{2}\frac{1}{2}$.

Cl: (4c) $\frac{1}{2}\frac{1}{2}\frac{1}{2}$ Si: (4d) $\frac{1}{4}\frac{1}{4}\frac{1}{4}$ Al(1): (4e) $\frac{3}{4}\frac{3}{4}\frac{3}{4}$
Si: (16a) $uuu;\ u\bar{u}\bar{u};\ \bar{u}u\bar{u};\ \bar{u}\bar{u}u$ with $u=0.117$
O(1): (16a) $u_1u_1u_1$ with $u_1=-0.177$
O(2): (16a) $u_2u_2u_2$ with $u_2=0.184$
(OH, F)(1): (24a) $u00;\ \bar{u}00;\ 0u0;\ 0\bar{u}0;\ 00u;\ 00\bar{u}$ with $u=0.273$
(OH, F)(2): (48d) $uuv;\ u\bar{u}\bar{v};\ \bar{u}u\bar{v};\ \bar{u}\bar{u}v;\ vuu;\ \bar{v}u\bar{u};\ \bar{v}\bar{u}u;\ v\bar{u}\bar{u};\ uvu;\ \bar{u}\bar{v}u;\ u\bar{v}\bar{u};\ \bar{u}v\bar{u}$ with $u=0.181$, $v=0.545$
O(3): (48d) $u'u'v'$ with $u'=0.139$, $v'=0.006$
Al(2): (48d) $u_1u_1v_1$ with $u_1=0.089$, $v_1=-0.228$.

(*bl*) The hexagonal unit of **cancrinite** contains one molecule whose ideal composition is said to be $Ca_2Na_6Al_6Si_6O_{24}\cdot 2CO_3$. An arrangement which is compared with some estimated intensity data from rotation photographs has been developed from C_6^6. It is as follows:

2 Ca: (b) $\frac{1}{3}\frac{2}{3}u$; $\frac{2}{3}$, $\frac{1}{3}$, $u+\frac{1}{2}$ with $u=0.36$
2 C: (b) $\frac{1}{3}\frac{2}{3}u'$; $\frac{2}{3}$, $\frac{1}{3}$, $u'+\frac{1}{2}$ with $u'=-0.14$.

The rest of the atoms are in general positions:

(c): xyz; $y-x$, $\bar{x}$, z; $\bar{y}$, $x-y$, z; $\bar{x}$, $\bar{y}$, $z+\frac{1}{2}$; $x-y$, x, $z+\frac{1}{2}$; y, $y-x$, $z+\frac{1}{2}$

with the parameters of Table XV.

TABLE XV. PARAMETERS FOR ATOMS OF CANCRINITE LYING IN GENERAL POSITIONS

Atom	*No. per cell*	*x*	*y*	*z*
Na	6	0.50	0.50	0.22
Si	6	.03	.26	.26
Al	6	.26	.23	.24
O(1)	6	.05	.36	.01
O(2)	6	.36	.32	−.03
O(3)	6	.17	.27	.26
O(4)	6	−.13	.16	.24
O(5)	6	.20	.64	.36

(*bm*) The **feldspars** have a grouping which thus far has resisted complete analysis. A few years ago (**1929**, 289a; **1931**, 391) a type of structure was proposed which did not provide reasonable interatomic distances. Recently a different arrangement has been suggested for a sanidine ($KAlSi_3O_8$, with some Na replacing K). This gives approximately the right atomic separations and is in fairly good agreement with the reflections on several rotation photographs. It has atoms in the following special and general positions of C_{2h}^3 with the parameters of Table XVI:

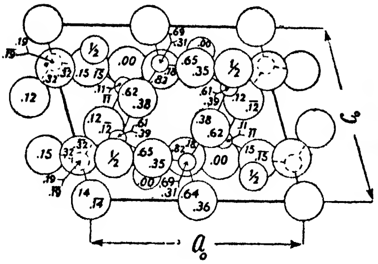
(g) $\pm(0u0)$; $\pm(\frac{1}{2}, u+\frac{1}{2}, 0)$ (i) $\pm(u0v)$; $\pm(u+\frac{1}{2}, \frac{1}{2}, v)$
(j) $\pm(xyz)$; $\pm(x\bar{y}z)$; $\pm(x+\frac{1}{2}, y+\frac{1}{2}, z)$; $\pm(x+\frac{1}{2}, \frac{1}{2}-y, z)$.

A projection of the unit cell on its ac-plane is reproduced in Figure 331. Its interlocking network of (Al, Si)O_4 tetrahedra is seen to be very different from those deduced for the sodalite and zeolitic minerals.

Measurements upon celsian, $BaAl_2Si_2O_8$, have indicated that it is triclinic but that it probably does not depart far from the monoclinic arrange-

TABLE XVI. PARAMETERS OF THE ATOMS IN SANIDINE

Atom	*No. per cell*	*Position*	*x*	*y*	*z*
O(1)	4	(g)	0	0.139	0
O(2)	4	(i)	0.658	0	0.236
O(3)	8	(j)	.819	.153	.236
O(4)	8	(j)	.000	.319	.250
O(5)	8	(j)	.153	.125	.417
Si+Al(1)	8	(j)	.000	.186	.217
Si+Al(2)	8	(j)	.703	.111	.347
K	4	(i)	.294	0	.139



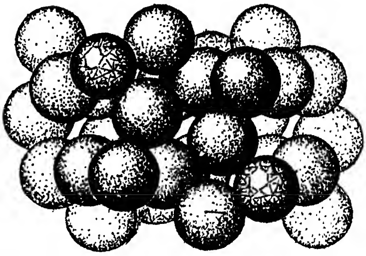


FIG. 331*a*.—(*left*) A portion of the monoclinic structure found for sanidine, $KAlSi_3O_8$, as projected on its b-face. The smallest circles are Al or Si (not distinguished in the structure), the largest are O atoms.

FIG. 331*b*.—(*right*) A packing drawing of *a*. The K ions are line-shaded; two of the (Si, Al) atoms are visible as black spheres.

ment of sanidine. The K-Ba feldspars, adularia and hyalophane, containing up to ca 15% BaO are truly monoclinic. In these minerals there is thought to be a haphazard replacement of K and Si by Ba and Al.

The soda feldspar albite, $NaAlSi_3O_8$, though definitely triclinic can be described in terms of a sanidine-like cell. It has been found that an arrangement with parameters modified from those of $KAlSi_3O_8$ yields fairly satisfactory agreement with photographic data. The cell for this description, being base-centered and hence not the simplest one possible has for its general positions the coordinates: (i) $\pm(xyz)$; $\pm(x+\frac{1}{2}, y+\frac{1}{2}, z)$. Its parameters are recorded in Table XVII. The similarity between this structure and the sanidine grouping is best seen by comparing this table with Table XVI.

TABLE XVII. PARAMETERS OF THE ATOMS IN ALBITE

Atom	*x*	*y*	*z*
O(1)	0.014	0.125	−0.014
O(2)	.611	−.014	.278
O(3, a)	.833	.125	.214
O(3, b)	.311	.361	.250
O(4, a)	.014	.305	.264
O(4, b)	.536	.194	.230
O(5, a)	.194	.139	.389
O(5, b)	.658	.389	.411
Si+Al(1, a)	.000	.175	.222
Si+Al(1, b)	.472	.328	.233
Si+Al(2, a)	.714	.105	.333
Si+Al(2, b)	.214	.383	.361
Na	.278	−.167	.172

All of the plagioclase feldspars do not have albite-like cells. The units of two andesites with albite-anorthite ratios of 3:1 and 2:1 are like albite, but anorthite itself, $CaAl_2Si_2O_8$, and a labradorite with the ratio 1:1 both have c_0 axes that are twice as long.

New data bearing on the cell dimensions of the feldspars are assembled in Table XVIII (cf. Table XVIII, p. 354 of book).

TABLE XVIII. NEW CELL DIMENSIONS ON FELDSPARS

Mineral	*Symmetry*	a_0	b_0	c_0	α	β	γ
Sanidine	Monoclinic	8.45	12.90	7.15	—	116°6′	—
Adularia	Monoclinic	8.45	12.90	7.15	—	116°3′	—
Hyalophane (A, B)	Monoclinic	8.45	12.90	7.15	—	115°35′	—
Hyalophane (C)	Monoclinic	8.52	12.95	7.14	—	115°35′	—
Celsian	Triclinic	8.63	13.10	7.29	ca 90°	116°	ca 90°
Albite	Triclinic	8.14	12.86	7.17	94°3′	116°29′	88°9′
Andesite	Triclinic	8.14	12.86	7.17	93°23′	116°28′	89°59′
Labradorite	Triclinic	8.21	12.95	14.16	93°31′	116°3′	89°55′
Anorthite	Triclinic	8.21	12.95	14.16	93°13′	115°56′	91°12′

(*bn*) An earlier (**1929**, 115) study of **wollastonite**, $CaSiO_3$, resulted in a monoclinic unit. More recently it has been shown to be triclinic. Similar cells can be given to pectolite, $NaHCa_2(SiO_3)_3$, and probably to schizolite, $HNa(Ca, Mn)_2(SiO_3)_3$.

(*bo*) The cell dimensions for **epidote** quoted in Table I are those of **1932**, 172. The two earlier studies gave it a two-molecule unit with a_0 half as long. Clinozoisite, an epidote without iron, is structurally like the ordinary variety.

(*bp*) The structure of **nephelite** is yet to be determined. A few suggestions have been made but, unsupported by the necessary X-ray data, they are of little value.

(*bq*) Unit cells have been assigned to two **wöhlerite**-like minerals besides the one quoted in Table I. Lavenite with 20% of its Zr replaced by Ca_2 has $a_0 = 10.93$ A, $b_0 = 9.99$ A, $c_0 = 7.18$ A, $\beta = 110°28'$; hiortdahlite with Ca_2 substituting for 25% of its (Zr, F)Na is reported to be triclinic but with very similar cell dimensions: $a_0 = 10.91$ A, $b_0 = 10.29$ A, $c_0 = 7.32$ A, $\alpha = 90°29'$, $\beta = 108°50'$, $\gamma = 90°8'$.

(*br*) **Mosandrite** is a rinkite in which H and OH replace Na and F atoms. Though monoclinic the cell dimensions found for it are nearly the same as those given to the orthorhombic rinkite. They are $a_0 = 18.47$ A, $b_0 = 5.67$ A, $c_0 = 7.46$ A, $\beta = 91°13'$.

(*bs*) The unit cubes of several **garnets** have been measured. One, a 48% grossularite-andradite, 52% almandite-pyrope, has $a_0 = 11.668$ A (**1933**, 182). Spessartite gives 11.603 A; partschinite, a spessartite with some iron in place of manganese has $a_0 = 11.613$ A (**1933**, 522). It has also been found that a_0 for Ca-Fe garnets increases from 11.93 A to 12.14 A as the titanium content mounts from zero.

(*bt*) It is suggested that though they seemingly are tetragonal, the **scapolites** really are complex twinnings of monoclinic and triclinic individuals.

Chapter XXA. Structures of Organic Compounds

Nearly all the X-ray studies of organic crystals being published are limited to unit cell and space group determinations. Some, as indicated in the large tables, prove molecular symmetry for suitably constituted compounds. Others point to the existence of associated molecules in the crystalline state. Though a few of these associations, marked A in the tables, may be real most of them are to be explained by the choice of too large a unit cell.

Some progress has been made towards an understanding of the atomic arrangements in aliphatic structures but most of the increase in our knowledge of atomic positions in organic crystals has come through the investigation of several aromatic hydrocarbons.

A. The Structures of Organic Salts and of Metallo-organic Compounds

(*bd*) A previous study of $\mathbf{Be_4O(C_2H_3O_2)_6}$ has indicated that the eight molecules in its unit cube are arranged according to the requirements of T_h^4. This has been confirmed and it has been shown that by placing atoms in the following positions of this space group an arrangement is obtained which yields plausible interatomic distances and does not conflict with data from Laue and oscillation photographs.

Be: (32b) uuu; etc. [see XVIIIA, (*ce*)] with $u=-0.060$
O(1): (8f) $000; \frac{1}{2}0\frac{1}{2}; \frac{1}{2}\frac{1}{2}0; 0\frac{1}{2}\frac{1}{2}; \frac{1}{4}\frac{1}{4}\frac{1}{4}; \frac{3}{4}\frac{1}{4}\frac{3}{4}; \frac{3}{4}\frac{3}{4}\frac{1}{4}; \frac{1}{4}\frac{3}{4}\frac{3}{4}$
O(2): (g) xyz; etc. with $x=-0.163$, $y=-0.064$, $z=-0.038$
C(1): (48c) u_100; etc. with $u_1=0.197$
C(2): (48c) $u'00$; etc. with $u'=0.295$.

As was earlier pointed out this choice of space group implies that the two oxygen atoms of the acetate group are geometrically equivalent.

(*be*) Two studies of the dihydrate of **copper formate**, $Cu(HCOO)_2 \cdot 2H_2O$, differ both in the size of the unit and in the chosen space group.

(*bf*) It is said that the lead atoms in $Pb(HCOO)_2$ have the coordinates $\frac{1}{12}, \frac{1}{12}, \frac{1}{4}; \frac{11}{12}, \frac{11}{12}, \frac{3}{4}; \frac{5}{12}, \frac{7}{12}, \frac{1}{4}; \frac{7}{12}, \frac{5}{12}, \frac{3}{4}$.

TABLE I. THE CRYSTAL STRUCTURES OF ORGANIC SALTS AND METALLO-ORGANIC COMPOUNDS

Substance, symmetry and type			*Space group*	*No. mol. per cell*	*Min. mol. symmetry*	a_o	b_o	c_o	*References*
Silver Nitrate Urea $AgNO_3 \cdot CO(NH_2)_2$	Mon.		C^2_{2h}	8	A	10.23	16.84 $\beta = 77°$	6.25	**1934, 55.**
Mellite $Al_2C_{12}O_{12} \cdot 18H_2O$	Tet.			16		22.0		23.3	**1933, 31.**
Barium Chloride Glycine $BaCl_2 \cdot 2CH_2NH_2COOH$	Ort.		V^{16}_h	4	C_i or C_s	7.96	14.7	9.21	**1933, 41.**
Beryllium Oxyacetate $Be_4O(C_2H_3O_2)_6$	Cub.	(*j*), (*bd*)							**1934, 206.**
Triphenyl Bismuthine Dichloride	Ort.		V^2	8	A	17.31	22.39	9.20	**1931, 138.**
Calcium Sulfate Urea $CaSO_4 \cdot CO(NH_2)_2$	Tri.			4	A	14.74 $\alpha = 91°26'$,	14.95 $\beta = 90°22'$,	6.47 $\gamma = 86°42'$	**1933, 179.**
Cesium Acid Tartrate $CsHC_4H_4O_6$	Ort.			4		7.66	11.58	8.03	**1931, 169.**
Copper Formate Dihydrate $Cu(HCO_2)_2 \cdot 2H_2O$	Mon.	(*be*)							**1931, 241, 364.**
Copper Formate Tetrahydrate $Cu(HCO_2)_2 \cdot 4H_2O$	Mon.								**1931, 241.**
Cuprous Glutathione	Ort.		V^4	4		28.0	8.74	5.57	**1932, 366.**
Potassium Acid Tartrate $KHC_4H_4O_6$	Ort.			4		7.614	10.70	7.80	**1932, 147.**
Rochelle Salt $NaOOC(CHOH)_2COOK \cdot 4H_2O$	Ort.		V^4	4		11.913	14.324	6.153	**1933, 444.**
Lead Formate $Pb(HCO_2)_2$	Ort.	(*b*), (*bf*)							**1932, 190.**

Substance, symmetry and type			Space group	No. mol. per cell	Min. mol. symmetry	a_0	b_0	c_0	References
Bisethylene Diamino Platinous Chloride $Pt(C_2H_8N_2)_2Cl_2$	Tri.		C_i^1	1		8.37 $\alpha=100°46'$,	4.95 $\beta=111°40'$,	6.86 $\gamma=81°56'$	1933, 109.
α-Bisdiethyl Sulfine Platinous Chloride $Pt[S(C_2H_5)_2]_2Cl_2$	Mon.			2		12.0	7.9 $\beta=93°56'$	7.7	1934, 61.
α-Bisdimethyl Sulfine Platinous Chloride $Pt[S(CH_3)_2]_2Cl_2$	Mon.		C_{2h}^2 or C_{2h}^5	2		10.16	6.01 $\beta=105°55'$	8.48	1934, 61.
β-Bisdimethyl Sulfine Platinous Chloride $Pt[S(CH_3)_2]_2Cl_2$	Mon.			4		9.3	13.2 $\beta=105°$	8.7	1934, 61.
Methyl Silicate $(CH_3)_4SiO_4$	Cub.	(*bg*)	T^1	4	C_3	9.85 at −80° C (?)			1931, 106.
Dimethyl Thallium Bromide $Tl(CH_3)_2Br$	Tet.	(*bh*)	D_{4h}^{17}	2	D_4^h	4.47		13.78	1934, 217.
Dimethyl Thallium Chloride $Tl(CH_3)_2Cl$	Tet.	(*bh*)	D_{4h}^{17}	2	D_4^h	4.29		14.01	1934, 217.
Dimethyl Thallium Iodide $Tl(CH_3)_2I$	Tet.	(*bh*)	D_{4h}^{17}	2	D_4^h	4.78		13.43	1934, 217.

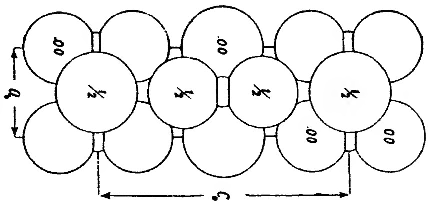


FIG. 332.—A projection upon one of its a-faces of atoms in the tetragonal arrangement deduced for $Tl(CH_3)_2I$. The largest circles are I ions, the slightly smaller ones are CH_3 groups. The sizes used in this drawing are determined by the results on the methyl substituted ammonium salts.

(*bg*) An elaborate discussion, based on powder photographs, has been given of possible arrangements for the atoms in **methyl silicate, $(CH_3)_4SiO_4$**. It was shown that the structure is based on T^1 but the correct grouping was not definitely established.

(*bh*) Spectral photographs have been used to find an atomic arrangement for the atoms in **dimethyl thallium iodide, $Tl(CH_3)_2I$**. They are in the following special positions of D_{4h}^{17}:

2 Tl: (a) 000; $\frac{1}{2}\frac{1}{2}\frac{1}{2}$ 2 I: (b) $\frac{1}{2}\frac{1}{2}0$; $00\frac{1}{2}$
$4(CH_3)$: (e) 00u; $00\bar{u}$; $\frac{1}{2}, \frac{1}{2}, u+\frac{1}{2}$; $\frac{1}{2}, \frac{1}{2}, \frac{1}{2}-u$ with u=ca 0.15.

The Tl-CH_3 separation is 2.01 A; the distance between CH_3 groups through which contact is made along c, is 4.17 A (Figure 332). This large CH_3-CH_3 separation may mean that u should be greater than 0.15.

The bromide and chloride are structurally isomorphous with the iodide but the methyl parameter could not be found for them.

B. The Structures of Substituted Ammonium Salts

(*bi*) Quantitative spectrometer measurements have been used to find the structure of **dimethyl ammonium chlorostannate**, $[NH_2(CH_3)_2]_2SnCl_6$. Atoms are in special and general positions of C_{2v}^7:

(a) 0uv; $\frac{1}{2}, \bar{u}, v+\frac{1}{2}$ (b) xyz; $\frac{1}{2}-x, \bar{y}, z+\frac{1}{2}$; $x+\frac{1}{2}, \bar{y}, z+\frac{1}{2}$; $\bar{x}yz$

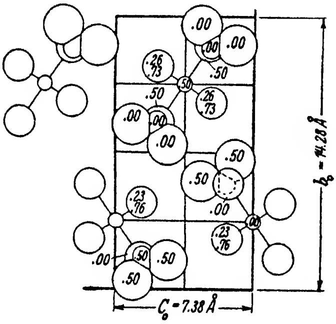
TABLE II. THE CRYSTAL STRUCTURES OF SUBSTITUTED AMMONIUM SALTS

Substance, symmetry and structure type		a_0	b_0	c_0	*No. mol. per cell*	*References*
Monomethyl Ammonium Cupric Chloride						
$(NH_3CH_3)_2CuCl_4$	Ort.	7.30	7.535	18.55	4	**1933, 157.**
Dimethyl Ammonium Chlorostannate						
$[NH_2(CH_3)_2]_2SnCl_6$	Ort. (*bi*)	7.26	14.28	7.38	2	**1933, 157; 1934, 60.**
Tetramethyl Ammonium Fluosilicate						
$[N(CH_3)_4]_2SiF_6$	Tet. (*bj*)	7.88		11.19	2	**1934, 57.**
n-Monoamyl Ammonium Chloride						
n-$C_5H_{11}NH_3Cl$	Tet. (*bk*)	7.03 at −80° C		16.70	4	**1933, 438.**
Octadecyl Ammonium Chloride						
$C_{18}H_{37}NH_3Cl$	Ort. (*bl*)	5.45	5.40	69.4	4	**1932, 41, 42.**

with the parameters of Table III. The axes of this description, XYZ= abc, are connected with those used for an earlier crystallographic description, a′b′c′, by the relations X=a=a′, Y=b=c′, Z=c=b′.

TABLE III. PARAMETERS OF THE ATOMS IN $[(CH_3)_2NH_2]_2SnCl_6$

Atom	*No. per cell*	*Position*	*x*	*y*	*z*
Sn	2	(a)	0	0.250	0
Cl(1)	2	(a)	0	.390	0.180
Cl(2)	2	(a)	0	.110	−.180
Cl(3)	4	(b)	0.235	.185	.190
Cl(4)	4	(b)	.235	.315	−.190
N(1)	2	(a)	0	.620	.690
N(2)	2	(a)	0	.880	.310
$CH_3(1)$	2	(a)	0	.605	.875
$CH_3(2)$	2	(a)	0	.895	.125
$CH_3(3)$	2	(a)	0	.530	.625
$CH_3(4)$	2	(a)	0	.970	.375



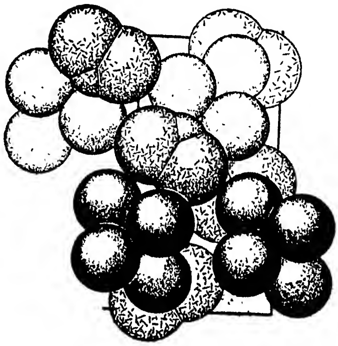
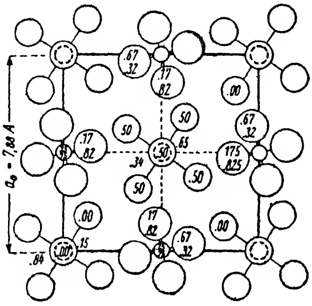


FIG. 333*a*.—(*left*) A portion of the structure of $[NH_2(CH_3)_2]_2SnCl_6$ projected on the a-face of its orthorhombic cell. The segments of circles, representing NH_2, join CH_3 groups (largest circles). The Cl and Sn (smallest circles) of $SnCl_6$ ions are connected by light lines.

FIG. 333*b*.—(*right*) A packing drawing of *a*. The $NH_2(CH_3)_2$ ions are line-shaded Atoms of Sn cannot be seen.

The substituted ammonium chlorostannates thus far analyzed have been relatively simple distortions of the $(NH_4)_2PtCl_6$ grouping [XVII, (*a*)]. This arrangement (Figure 333) can be similarly viewed but the distortion is great. The two C-N bonds of a $(CH_3)_2NH_2^+$ ion make the tetrahedral angle with one another; the CH_3-Cl separation, ca 3.83 A, is the same as that found in other substituted ammonium chlorostannates.

(*bj*) The tetragonal packing found for the atoms in **tetramethyl ammonium fluosilicate,** $[N(CH_3)_4]_2SiF_6$, is a distortion of that prevailing in the cubic $[N(CH_3)_4]_2SnCl_6$ (*u*). Atoms are in the following general and special positions (**1930**, 352, p. 82) of C_{4h}^5 with parameters fixed by a series of spectrometric measurements (Figure 334):



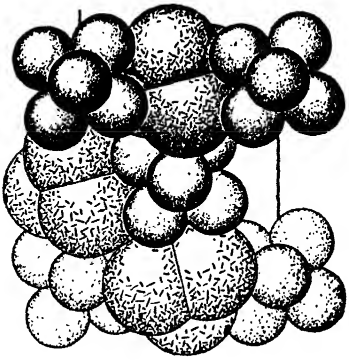


FIG. 334a.—(*left*) A basal projection of the tetragonal arrangement found for $[N(CH_3)_4]_2SiF_6$. The smallest circles, as N atoms, are each joined to their four surrounding CH_3 groups by light lines. The heavy dotted circles are the Si atoms at the centers of their surrounding F octahedra.

FIG. 334b.—(*right*) A packing drawing of *a*. The CH_3 groups of the $N(CH_3)_4$ tetrahedra are line-shaded.

2 Si: (a) $000; \frac{1}{2}\frac{1}{2}\frac{1}{2}$ 4 N: (d) $0\frac{1}{2}\frac{1}{4}; \frac{1}{2}0\frac{1}{4}; 0\frac{1}{2}\frac{3}{4}; \frac{1}{2}0\frac{3}{4}$
4 F: (e) $00u; 00\bar{u}; \frac{1}{2}, \frac{1}{2}, u+\frac{1}{2}; \frac{1}{2}, \frac{1}{2}, \frac{1}{2}-u$ with $u=0.155$
8 F: (h) $\pm(uv0); \pm(\bar{v}u0); \pm(\frac{1}{2}-v, u+\frac{1}{2}, \frac{1}{2}); \pm(u+\frac{1}{2}, v+\frac{1}{2}, \frac{1}{2})$ with $u=0.18, v=0.12$
16(CH_3): (i) $\pm(xyz); \pm(\bar{y}xz); \pm(\bar{x}\bar{y}z); \pm(y\bar{x}z)$ and eight similar points around $\frac{1}{2}\frac{1}{2}\frac{1}{2}$, with $x=0.14, y=0.47, z=0.175$.

(*bk*) In contrast with the two-molecule tetragonal cell found at room temperature, a four-molecule tetragonal unit is observed for **n-amyl ammonium chloride** both at CO_2-snow and at liquid air temperatures. The observed data are said to indicate that at low temperatures molecular rotation is arrested but not necessarily with the carbon chains in equilibrium positions.

(*bl*) The orthorhombic arrangement found for **octadecyl ammonium chloride** is said to be evidence that in this long chain compound the molecules are not rotating.

C. The Structures of Aliphatic and Aromatic Compounds

Aliphatic Compounds

(*bm*) A redetermination of a_0 for **methane** yields a value much lower than that previously found and in better agreement with the experimental density. The attempt to establish hydrogen positions from these photographs is undoubtedly of little real significance.

TABLE IV. THE CRYSTAL STRUCTURES OF ALIPHATIC ORGANIC COMPOUNDS

Substance, symmetry and type			*Space group*	*No. mol. per cell*	*Min. mol. symmetry*	a_o	b_o	c_o	*References*
Methane and Ethane Derivatives									
Methane CH_4	Cub.	(*y*), (*bm*)	T_d^2 (?)	4	T_d	5.89			1931, 307, 308, 309.
Iodoform CHI_3	Hex.	(*z*), (*bn*)	C_6^6	2	C_3	6.818		7.524	1931, 221.
Pentaerythritol Tetrabromide $C(CH_2Br)_4$	Mon.	(*bo*)	C_{2h}^1	1	C_2^h	7.199	6.325 $\beta = 112°52'$	5.719	1932, 457.
Pentaerythritol Tetrachloride $C(CH_2Cl)_4$	Mon.	(*bo*)	C_{2h}^1	1	C_2^h	6.912	6.289 $\beta = 112°54'$	5.492	1932, 457.
Pentaerythritol Tetraiodide $C(CH_2I)_4$	Mon.	(*bo*)		1		7.552	6.432 $\beta =$ ca 113°	6.075	1932, 457.
Urea $CO(NH_2)_2$	Tet.	(*aa*), (*bp*)	V_d^3	2	C_2^v				1932, 484; 1934, 303.
Thiourea $CS(NH_2)_2$	Ort.	(*ab*), (*bq*)	V_h^{16}	4	C_s	5.50	7.68	8.57	1932, 485.
Methyl Urea $CONH_2(NHCH_3)$	Ort.	(*ac*), (*br*)	V^4	4		6.89	6.96	8.45	1925, 281; 1933, 103.
Guanidinium Chloride $(NH_2)_2CNH \cdot HCl$	Ort.		V_h^{15}	8		7.76	9.22	13.06	1931, 444.
Hexabromobutylene $CHBr_2BrC=CBrCHBr_2$	Mon.		C_{2h}^5	2	C_i	11.5	6.40 $\beta = 44°27'$	10.06	1931, 104; 1932, 142.
Hexamethylethane $C_2(CH_3)_6$	Cub.			2		7.69			1934, 289.
Hexachlorethane (above 71° C) C_2Cl_6	Cub.			2		7.43 at 80° C			1934, 289.

Amino Acids

α-Glycine CH_2NH_2COOH	Mon.	(*bs*)	C_{2h}^5	4		5.04	12.1 $\beta=111°38'$	5.41	1931, 41, 173.
β-Glycine CH_2NH_2COOH	Mon.	(*bs*)	C_s^2	2		5.18	6.18 $\beta=114°20'$	5.29	1931, 41.
d-Alanine $CH_3CH(NH_2)COOH$	Ort.		V^4	4		6.0	12.1	5.75	1931, 41.
dl-Alanine $CH_3CH(NH_2)COOH$	Ort.		C_{2v}^9	4		6.0	12.0	5.8	1931, 41.
α-Glycylglycine $CH_2NH_2CONHCH_2COOH$	Mon.	(*bt*)	C_{2h}^5	4		7.76	9.46 $\beta=99°30'$	7.67	1931, 41; 1932, 283.
β-Glycylglycine $CH_2NH_2CONHCH_2COOH$	Mon.		C_{2h}^5	4		17.3	4.65 $\beta=125°20'$	8.4	1931, 41.
γ-Glycylglycine $CH_2NH_2CONHCH_2COOH$	Ort.		C_{2v}^5	4		8.1	9.36	7.7	1931, 41.
Asparagine Monohydrate $(CONH_2)CHNH_2CH_2COOH \cdot H_2O$	Ort.		V^4	4		5.6	11.8	9.86	1931, 41.
d-Alanylglycine $NH_2 \cdot CH(CH_3)CONHCH_2COOH$	Mon.			2		5.29	11.67 $\beta=101°30'$	5.47	1932, 283.
α-Diglycylglycine $NH_2CH_2CONHCH_2CONHCH_2COOH$	Mon.			2		8.53	4.3 $\beta=105°30'$	11.4	1932, 283.
β-Diglycylglycine $NH_2CH_2CONHCH_2CONHCH_2COOH$	Mon.			4		14.6	4.79 $\beta=105°30'$	11.67	1932, 283.
Diglycylglycine Dihydrate $NH_2CH_2CONHCH_2CONHCH_2COOH \cdot 2H_2O$	Ort.		C_{2v}^5	4		22.0	9.8	4.7	1931, 41.
l-Aspartic Acid $COOH \cdot CH_2 \cdot CH(NH_2)COOH$	Mon.		C_2^2	4	A	5.1	6.9 $\beta=96°$	15.1	1931, 41.
l-Glutamic Acid $COOH \cdot CH_2 \cdot CH_2CH(NH_2)COOH$	Ort.		V^4	4		7.06	10.3	8.75	1931, 41.
l-Cystine $COOHCH(NH_2)CH_2S{=}SCH_2CH(NH_2)COOH$	Hex.	(*bu*)							1931, 22, 41.

Substance, symmetry and type	*Space group*	*No. mol. per cell*	*Min. mol. symmetry*	a_o	b_o	c_o	*References*
Other Dicarboxylic Acid Derivatives							
Oxalic Acid Dihydrate Mon. (*cp*) $(COOH)_2\cdot 2H_2O$	C_{2h}^5	2	C_i	6.12	3.61 $\beta=106°12'$	12.03	**1934**, 305a.
α-Malonic Acid Ort. $COOHCH_2COOH$ (form stable above 80° C)		16		8.70	11.53	17.05	**1931**, 98; **1932**, 131.
β-Succinic Acid Mon. (*bv*) $COOH(CH_2)_2COOH$ (room temp. form)							**1930**, 383; **1931**, 98; **1932**, 131.
α-Succinic Acid Mon. $COOH(CH_2)_2COOH$ (second modification)	C_{2h}^3	8		5.70	26.28 $\beta=115°45'$	7.57	**1931**, 98; **1932**, 131.
α-Glutaric Acid Mon. $COOH(CH_2)_3COOH$	C_{2h}^6	8		10.34	5.08 $\beta=129°0'$	32.9	**1932**, 131, 132.
β-Glutaric Acid Mon. $COOH(CH_2)_3COOH$	C_{2h}^6			10.06	4.87 $\beta=132°35'$	17.4	**1932**, 131, 132.
Guanidine d-Tartrate Hydrate $[C(NH_2)_2NH]_2(C_4H_6O_6)\cdot 1\frac{1}{2}H_2O$ Mon.		2		9.88	14.77 $\beta=104°57'$	4.78	**1933**, 458.
Long Chain Derivatives							
Dodecanol Hex. (*bw*) $C_{12}H_{25}OH$	D_{3d}^3	1	D_3^d	4.76		34.0	**1932**, 41, 42.
Hexadecanol Mon. $C_{16}H_{33}OH$	C_{2h}^4	4		8.80	4.90 $\beta=56°40'$	44.2	**1932**, 41.
α-Palmitic Acid Mon. $CH_3(CH_2)_{14}COOH$		4		9.41	5.00 $\beta=50°33'$	46.1	**1932**, 131, 133, 441.
α-Stearic Acid Mon. $CH_3(CH_2)_{16}COOH$		4		9.41	5.00 $\beta=50°50'$	45.9	**1932**, 131, 440.

β-Stearic Acid $CH_3(CH_2)_{16}COOH$	Mon.	(*ao*)	C_{2h}^4 or C_{2h}^5	4		5.54	7.38 β=63°38′	48.84	**1932**, 131, 133, 440.
Saturated Cyclohydrocarbons and their Derivatives									
Cyclohexane C_6H_{12}	Cub.		T_h^2 or O_h^4	4	C_3^i	8.41 at CO_2-acetone temp.			**1930**, 122a.
1, 4 Dibromocyclohexane $C_6H_{10}Br_2$	Mon.	(*bx*)	C_{2h}^5	2	C_i	11.92	5.56 β=101°49′	6.02	**1931**, 161; **1932**, 191.
1, 4 Diiodocyclohexane $C_6H_{10}I_2$	Mon.	(*bx*)	C_{2h}^5	2	C_i	12.50	5.72 β=98°0′	6.20	**1931**, 161; **1932**, 191.
α-Cyclohexandiol 1, 2 $C_6H_{10}(OH)_2$	Ort.		V_h^{15}	8		7.62	8.55	19.57	**1931**, 473.
β-Cyclohexandiol 1, 4 $C_6H_{10}(OH)_2$	Mon.		C_{2h}^5	6		6.32	21.2 β=96°	7.27	**1931**, 473; **1932**, 192.
γ-Cyclohexandiol 1, 2 $C_6H_{10}(OH)_2$	Mon.		C_{2h}^6	8		19.13	9.92 β=103°54′	7.23	**1931**, 473.
β-Cyclohexandiol Diacetate 1, 4 $C_6H_{10}(CH_3CO_2)_2$	Mon.		C_{2h}^5	2	C_i	13.56	5.83 β=107°24′	6.72	**1931**, 473.
Quercitol $C_6H_7(OH)_5$	Mon.		C_2^2	2		6.83	8.53 β=110°57′	6.45	**1931**, 471.
l-Inositol $C_6H_6(OH)_6$	Mon.		C_2^2	2		6.17	9.11 β=106°36′	6.83	**1931**, 471.
i-Inositol $C_6H_6(OH)_6$	Mon.		C_{2h}^5	8	A	6.64	12.0 β=105°48′	19.7	**1931**, 471.
i-Inositol Dihydrate $C_6H_6(OH)_6 \cdot 2H_2O$	Mon.		C_{2h}^5	4		8.98	16.59 β=109°48′	6.49	**1931**, 472.
Methyl-l-Inositol $C_6H_6(OH)_5(OCH_3)$ (Quebrachitol)	Mon.		C_2^2	2		6.60	7.15 β=90°	8.65	**1931**, 350.
Cyclododecane $C_{12}H_{24}$	Tri.			1		7.84	5.44 α=81°42′, β=64°, γ=81°	7.82	**1933**, 307.

Substance, symmetry and type			*Space group*	*No. mol. per cell*	*Min. mol. symmetry*	a_o	b_o	c_o	*References*
Hexamethylenetetramine $C_6H_{12}N_4$	Cub.	(*as*), (*cq*)	T_d^4	2	T				**1934**, 303.
Cyclotetracosane 1, 13 dion $C_{24}H_{44}O_2$	Mon.			4		9.91	8.13 $\beta=68°30'$	30.79	**1933**, 307.
Cyclooctacosane 1, 15 dion $C_{28}H_{52}O_2$	Mon.			4		9.96	8.09 $\beta=68°30'$	35.78	**1933**, 307.
Sugars, etc.									
l-Arabinose $C_5H_{10}O_5$	Ort.		V^4	4		6.48	19.30	4.81	**1931**, 14, 90; **1932**, 113a.
l-Xylose $C_5H_{10}O_5$	Ort.		V^4	4		9.21	12.48	5.56	**1931**, 14, 90.
d-Glucose $C_6H_{12}O_6$	Ort.	(*ap*)							**1931**, 423.
d-Mannose $C_6H_{12}O_6$	Ort.		V^4	4		5.53	17.66	7.59	**1931**, 291, 293; **1932**, 293, 300.
β-α-Galactose $C_6H_{12}O_6$	Ort.		V^4	4		12.50	7.67	7.75	**1934**, 27.
l-Rhamnose Monohydrate $C_6H_{12}O_5 \cdot H_2O$	Mon.		C_2^2	2		7.84	7.84 $\beta=95°$	6.61	**1931**, 14, 90.
d-Mannitol $C_6H_{14}O_6$	Ort.	(*ap*)	V^4	4		8.66	16.58	5.50	**1931**, 284, 291, 293; **1932**, 293, 300.
Dulcitol $C_6H_{14}O_6$	Mon.		C_{2h}^5	4		8.61	11.60 $\beta=113°45'$	9.05	**1931**, 291, 293; **1932**, 300.
α-Methyl-l-Arabinoside $C_6H_{12}O_5$	Ort.		V^4	4		9.32	16.92	4.68	**1933**, 108; **1934**, 27.

β-Methyl-l-Arabinoside $C_6H_{12}O_5$	Ort. Form		V^4	4		16.56	7.74	5.89	**1933**, 108.
β-Methyl-l-Arabinoside $C_6H_{12}O_5$	Mon. Form		C_2^2 or C_{2h}^2	2		8.96	7.73 β=115°54′	5.94	**1934**, 27.
2, 3, 4 Trimethyl-δ-l-Arabonolactone	Ort.		V^4	4		10.8	12.2	7.30	**1931**, 492.
α-Methylxyloside $C_6H_{12}O_5$	Mon.		C_2^2	4	A	11.28	6.72 β=112°12′	11.02	**1932**, 115; **1934**, 27.
β-d-Methylxyloside $C_6H_{12}O_5$	Mon.		C_2^2	2		7.82	6.89 β=113°10′	7.74	**1932**, 113.
2, 3, 4 Trimethyl-α-d-Xylopyranose	Mon.		C_2^2	2		8.68	8.31 β=91°0′	6.65	**1931**, 492.
β-d-Glucosan $C_6H_{10}O_5$	Ort.		V^4	4		6.65	13.14	7.46	**1933**, 108.
Methyl-l-Rhamnoside $C_7H_{14}O_5$	Ort.		V^4	4		8.26	13.31	7.54	**1934**, 27.
α-Methyl-d-Glucoside $C_7H_{14}O_6$	Ort.	(*ap*)	V^4	4		11.21	14.57	5.29	**1933**, 108.
β-Methyl-d-Glucoside Hemihydrate $C_7H_{14}O_6 \cdot \frac{1}{2}H_2O$	Tet.		D_4^4	8		7.32		33.6	**1933**, 108.
1, 3, 4, 5 Tetramethyl-β-d-Fructopyranose	Ort.		V^4	4		9.22	8.97	14.8	**1931**, 492.
1, 3, 4, 5 Tetraacetyl-β-d-Fructopyranose	Mon.		C_2^1	2		10.7	7.98 β=144°30′	17.0	**1931**, 492.
α-Methylmannoside (m. p. 193° C) $C_7H_{14}O_6$ (pyranose form)	Ort.		V^4	4		9.38	9.99	9.23	**1932**, 118.
α-Methylmannoside (m. p. 118° C) $C_7H_{14}O_6$ (furanose form)	Ort.		V^4	4		15.87	11.73	4.64	**1932**, 118.
γ-d-Mannonolactone	Ort.			4		14.0	11.1	4.73	**1931**, 492.

Substance, symmetry and type	*Space group*	*No. mol. per cell*	*Min. mol. symmetry*	a_o	b_o	c_o	*References*
2, 3, 5, 6 Tetramethyl-γ-d-Mannonolactone Mon.	C_2^2	2		9.79	13.8 $\beta=93°18'$	4.50	**1931**, 492.
γ-Monoacetylmethyl-l-Rhamnoside $C_9H_{16}O_6$ Ort.	V^4	4		7.98	18.25	7.08	**1933**, 108.
Glucose Pentaacetate Ort.		4		24.3	14.9	5.65	**1934**, 151.
2, 3, 5 Trimethyl-γ-l-Rhamnonolactone Ort.	V^1	4		12.2	18.3	4.65	**1931**, 492.
d-Chitosamine Hydrochloride $C_6H_{14}O_5NCl$ Mon.	C_2^2	2		7.68	9.18 $\beta=112°29'$	7.11	**1933**, 108.
Cellulose $(C_6H_{10}O_5)_n$ (*by*)							**1930**, 448; **1931**, 21, 82, 491.
Cellulose Hydrate Mon. (*by*)				8.14	10.3 $\beta=62°$	9.14	**1929**, 46; **1933**, 402.
Cellulose Perchlorate $2C_6H_{10}O_5 \cdot HClO_4$ Mon. (*by*)				16.5	10.3 $\beta=93°$	10.7	**1930**, 372.

(*bn*) A further study of the structure of **iodoform, CHI_3,** using photographic data, has confirmed the previous choice of space group and iodine positions. Carbon atoms are thought to be in $\frac{1}{3}\frac{2}{3}u$; $\frac{2}{3}$, $\frac{1}{3}$, $u+\frac{1}{2}$ with u between 0.50 and 0.60.

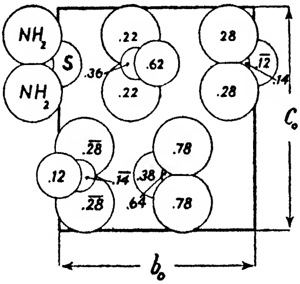
(*bo*) If the space group assigned to these **pentaerythritol tetrahalides** is correct, their molecules cannot have tetrahedral symmetry.

(*bp*) Additional spectrometric measurements on **urea** and their Fourier analyses have led to the following more accurate parameters (see book, p. 373): u(C)=0.335, v(O)=0.60, w(N)=0.145, t(N)=0.18.

(*bq*) Spectrometric measurements of intensity and Fourier analyses have been used in a reexamination of the structure of **thiourea, $CS(NH_2)_2$.** Atoms are in the positions of V_h^{16} previously chosen, (*ab*), with the parameters (the origin in a center of symmetry):

C: (c) $\pm(uv\frac{1}{4})$; $\pm(\frac{1}{2}-u, v+\frac{1}{2}, \frac{1}{4})$ with $u=-0.14$, $v=0.10$
S: (c) $\pm(u_1v_1\frac{1}{4})$; etc. with $u_1=0.120$, $v_1=-0.007$
N: (d) $\pm(xyz)$; $\pm(x, y, \frac{1}{2}-z)$; $\pm(x+\frac{1}{2}, \frac{1}{2}-y, z+\frac{1}{2})$; $\pm(x+\frac{1}{2}, \frac{1}{2}-y, \bar{z})$
with $x=0.278$, $y=-0.130$, $z=-0.125$.

The way the molecules pack together is illustrated by Figure 335. In contrast with the earlier arrangement all the atoms in a molecule lie in one plane. The C-S separation is 1.64 A; NH_2 and S of different molecules are 3.45 A apart. Other interatomic distances are practically the same as in urea.



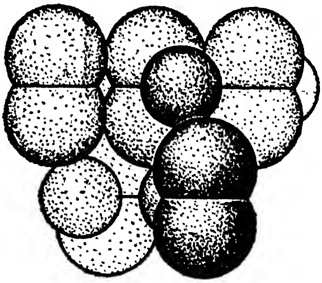


FIG. 335*a*.—(*left*) The orthorhombic structure of thiourea projected on the a-face.
FIG. 335*b*.—(*right*) A packing drawing of *a*. The C atoms do not appear.

(*br*) Spectrometric measurements of crystals of **methyl urea**, $CONH_2\cdot(NHCH_3)$, have been made in an attempt to find its complete structure. All atoms are in general positions of V^4. Values of x and y atomic parameters have been determined from structure factor calculations and Fourier analysis. They account for all the (hk0) reflections but a satisfactory structure using them in an explanation of the more complicated (h0l) data was not found.

(*bs*) A structure for the ordinary (α) form of **glycine**, CH_2NH_2COOH, has been deduced which is in good agreement with spectrometric measurements of the simplest reflections but which like that mentioned for methyl urea, (*br*), is unable to explain the more complex intensities. In this proposed arrangement all atoms are in general positions of C_{2h}^5: (e) ±(xyz); $\pm(\frac{1}{2}-x, y+\frac{1}{2}, \frac{1}{2}-z)$ with the parameters of Table V.

It has been reported that X-ray results indicate the reality of the supposed β-modification of glycine but the published evidence for this conclusion is not convincing.

TABLE V. PARAMETERS OF THE ATOMS IN GLYCINE

Atom	*No. per cell*	*x*	*y*	*z*
O(1)	4	0.42	0.35	0.74
O(2)	4	.44	.47	.63
N	4	.88	.33	.15
C(1)	4	.22	.41	.58
C(2)	4	.12	.40	.26

(*bt*) By choosing axes in the ac-plane different from those of Table IV, **α-glycylglycine** has been given a four-molecule cell with the dimensions $a_0=7.7$, $b_0=9.56$, $c_0=9.5$, $\beta=125°20'$ (**1931**, 41).

(*bu*) Conflicting cell dimensions have been published for the hexagonal crystals of **l-cystine**. One determination (**1931**, 41), choosing D_6^2 as space group, finds a six-molecule cell with $a_0=5.40$ A, $c_0=57.8$ A. The other with three molecules in its unit has $a_0=9.40$ A, $c_0=9.42$ A (**1931**, 22).

(*bv*) Recent measurements of the unit cell of the room temperature form of **succinic acid** (**1931**, 98; **1932**, 131) confirm a previous assignment of unit cell.

(*bw*) The simple hexagonal unit found for **dodecanol** at room temperature is considered to show that its molecules are rotating.

(*bx*) Positions have been found for the iodine atoms in **1,4 diiodocyclohexane**. They are in general positions of C_{2h}^5: (e) ±(xyz); $\pm(x+\frac{1}{2}, \frac{1}{2}-y, z)$ with x=0.150, y=0.135 or 0.365, z=0.385. An earlier space group assignment, of C_{2h}^4 (**1931**, 161), was wrong for this compound and for the isomorphous dibromide.

(*by*) Debate over the unit cell and structure of cellulose continues, the symmetry being sometimes treated as tetragonal, sometimes as orthorhombic and sometimes as monoclinic. The last is most probably correct. It is obvious that from the standpoint of sound crystal analysis the arrangements frequently described for cellulose and its derivatives must be considered as speculations, more or less compatible with chemical information, and perhaps not conflicting with the very limited X-ray data at hand. Assignments of positions to the atoms in rubber, in silk fibroin and in most other macromolecular substances are equally uncertain.

Aromatic Compounds

Greater progress has been made in determining atomic positions in crystals of aromatic compounds. This is largely due to the fact that their benzene rings provide large building blocks that always have the same size and shape and can enter into the known units in only a limited number of ways.

(*bz*) It has been found that the iodine atoms in **o-iodobenzoic acid**, C_6H_4ICOOH, are in general positions of C_{2h}^5: (e) $\pm(xyz)$; $\pm(x+\frac{1}{2}, \frac{1}{2}-y, z)$ with the parameters $x=0.14$, $y=0.08$, $z=0.02$. The positions of the other atoms are not known.

(*ca*) **p-Dibromobenzene**, $C_6H_4Br_2$, has its bromine atoms in general positions of C_{2h}^5: (e) $\pm(xyz)$; $\pm(\bar{x}, y+\frac{1}{2}, \frac{1}{2}-z)$ with $x=0.03$, $y=0.167$, $z=0.170$. For the isomorphous chloride $x_1=0.04$, $y_1=0.16$, $z_1=0.16$. Parameters compatible with atomic packing and with observed optical properties have been suggested for the carbon atoms. The available X-ray data are not able to show whether these carbon positions are right.

The diffraction effects of p-bromochlorobenzene, C_6H_4BrCl, are intermediate between those of the chlorine and bromine derivatives. This presumably means that the molecules go into the structure, with half the bromine atoms pointing one way and with the other half pointing in the opposite direction.

(*cb*) The **p-diiodobenzene, $C_6H_4I_2$,** is not isomorphous with its chloro- and bromo-analogues. Iodine atoms in the orthorhombic unit are in general positions of V_h^{15}: (c) $\pm(xyz)$; $\pm(x+\frac{1}{2}, \frac{1}{2}-y, \bar{z})$; $\pm(\bar{x}, y+\frac{1}{2}, \frac{1}{2}-z)$; $\pm(\frac{1}{2}-x, \bar{y}, z+\frac{1}{2})$ with $x=0.172$, $y=0.40$, $z=0.22$.

m-Diiodobenzene also is orthorhombic. Iodine atoms are at $\pm(uv\frac{1}{4})$; $\pm(u\bar{v}\frac{3}{4})$; $\pm(u+\frac{1}{2}, v+\frac{1}{2}, \frac{1}{4})$; $\pm(\frac{1}{2}-u, v+\frac{1}{2}, \frac{1}{4})$ with $u=0.172$, $v=0.200$. The space group may be C_{2v}^{12}.

(*cc*) A thorough study, including spectrometric measurements and a Fourier analysis, has been made of the crystal structure of **durene**, 1, 2, 4, 5 $C_6H_2(CH_3)_4$. All atoms are in general positions of C_{2h}^5: (e) $\pm(xyz)$; $\pm(x+\frac{1}{2}, \frac{1}{2}-y, z)$ with the parameters listed in Table VII. This arrangement (Figure 336) gives a molecule that, like $C_6(CH_3)_6$, is planar. The packing is, however, a totally different one. In this crystal the nearest approach of atoms belonging to adjacent molecules is relatively large—3.90 A.

(*cd*) The x and z parameters of both the chlorine and the carbon atoms in **C_6Cl_6** have been selected from a Fourier analysis of the spectrometrically determined (h0l) intensities. Data needed to establish the y parameters could not be obtained so that the structure remains only partly known.

TABLE VI. THE CRYSTAL STRUCTURES OF AROMATIC ORGANIC COMPOUNDS

Substance, symmetry and type			*Space group*	*No. mol. per cell*	*Min. mol. symmetry*	a_o	b_o	c_o	*References*
Benzene C_6H_6	Ort.	*(au)*							**1930**, 45a; **1932**, 117.
Phenylaminoacetic Acid $C_6H_5CHNH_2COOH$	Ort.								**1931**, 354.
d-Phenyl Alanine $C_6H_5CH_2 \cdot CH(NH_2)COOH$	Ort.		V^4	8	A	30.8	11.0	4.8	**1931**, 41.
o-Iodobenzoic Acid C_6H_4ICOOH	Mon.	*(bz)*	C_{2h}^5	4		11.30	15.17 $\beta=90°44'$	4.336	**1933**, 262.
p-Dibromobenzene $C_6H_4Br_2$	Mon.	*(ca)*	C_{2h}^5	2	C_i	4.11	5.80 $\beta=112°38'$	15.46	**1932**, 202.
p-Dichlorobenzene $C_6H_4Cl_2$	Mon.	*(ca)*	C_{2h}^5	2	C_i	4.10	5.88 $\beta=112°30'$	14.83	**1932**, 202.
p-Bromochlorobenzene C_6H_4BrCl	Mon.	*(ca)*	C_{2h}^5	2	C_i	4.13	5.81 $\beta=113°0'$	15.15	**1932**, 202.
o-Diiodobenzene $C_6H_4I_2$	Mon.			4		8.29	12.23 $\beta=93°56'$	7.91	**1933**, 181.
m-Diiodobenzene $C_6H_4I_2$	Ort.	*(cb)*	C_{2v}^{12}	4	C_s	17.20	7.08	6.21	**1933**, 181.
p-Diiodobenzene $C_6H_4I_2$	Ort.	*(cb)*	V_h^{15}	4	C_i	17.00	7.38	6.21	**1933**, 181.
p-Quinone $C_6H_4O_2$	Mon.	*(co)*	C_{2h}^5	2	C_i	7.08	6.79 $\beta=101°0'$	5.80	**1932**, 96; **1934**, 228.
Resorcinol m-$C_6H_4(OH)_2$	Ort.		C_{2v}^9	4		10.53	9.53	5.66	**1928**, 451; **1934**, 229a.
m-Dinitrobenzene $C_6H_4(NO_2)_2$	Ort.	*(av)*	V_h^{16}	4	C_s	13.27	14.06	3.820	**1931**, 171.

1, 2, 6 Dinitrophenol $C_6H_3OH(NO_2)_2$	Ort.		V_h^{11}	8		12.1	12.7	9.5	**1930**, 134.
2, 4, 6 Trinitrobromobenzene $C_6H_2Br(NO_2)_3$	Tri.			12*		15.2	15.4 $\alpha=74°$, $\beta=98°$, $\gamma=119°$	15.64	**1933**, 185.
2, 4, 6 Trinitrobromobenzene $C_6H_2Br(NO_2)_3$	Hex.			9		14.90		22.6	**1933**, 185.
2, 4, 6 Trinitrochlorobenzene $C_6H_2Cl(NO_2)_3$	Mon.		C_{2h}^3	8		24.9	6.8 $\beta=102°51'$	11.0	**1933**, 185.
Durene 1, 2, 4, 5 $C_6H_2(CH_3)_4$	Mon.	(*cc*)	C_{2h}^5	2	C_i	11.57	5.77 $\beta=113°18'$	7.03	**1933**, 377, 378.
2, 4, 6 Trinitroiodobenzene $C_6H_2I(NO_2)_3$	Tet.		$D_4^{4,8}$	4	C_2	7.03		19.80	**1933**, 185.
1, 2, 4, 6 Tetranitrobenzene $C_6H_2(NO_2)_4$	Ort.		V^4	4		12.4	6.15	13.1	**1933**, 185.
2, 4, 6 Trinitrotoluene $C_6H_2CH_3(NO_2)_3$	Mon.	(*ck*)	C_{2h}^6			40.5	6.19 $\beta=89°29'$	15.2	**1933**, 186.
2, 4, 6 Trinitroaniline $C_6H_2(NH_2)(NO_2)_3$	Mon.		C_{2h}^5	4		15.3	9.28 $\beta=99°12'$	6.01	**1933**, 185.
4 Nitro-2-Methylaminotoluene (yellow form)	Mon.		C_{2h}^5	4		17.2	12.2 $\beta=102°$	3.83	**1932**, 211.
4 Nitro-2-Methylaminotoluene (red form)	Tri.			2		7.6	8.5 $\alpha=113°$, $\beta=98°$, $\gamma=109°$	7.5	**1932**, 211.
Styphnic Acid $C_6H(OH)_2(NO_2)_3$	Hex.	(*cl*)	C_{3v}^3 or D_{3d}^4	6		12.7		10.0	**1931**, 190.
Hexachlorobenzene C_6Cl_6	Mon.	(*cd*)	C_{2h}^5	2	C_i	8.07	3.84 $\beta=116°52'$	16.61	**1931**, 283.
Hexaminobenzene $C_6(NH_2)_6$	Cub.		O_h^3	16	C_3	14.84 at −183° C			**1931**, 261.

* A triclinic unit containing as many molecules as 12 cannot possibly be the true one.

Substance, symmetry and type			*Space group*	*No. mol. per cell*	*Min. mol. symmetry*	a_o	b_o	c_o	*References*
2, 4, 6 Trinitrophloroglucinol $C_6(OH)_3(NO_2)_3$	Hex.	(*cl*)	C_{3v}^3 or D_{3d}^4	6		13.4		9.6	**1931**, 190.
Quinhydrone $C_6H_4O_2 \cdot C_6H_4(OH)_2$	Mon.	(*ce*)	C_{2h}^5	1		3.85	6.04 $\beta = 90°$	10.9	**1932**, 150.
p-Aminoazobenzene $C_6H_5N=NC_6H_4(NH_2)$	Mon.			4		13.69	5.604 $\beta = 81°49'$	14.18	**1933**, 365.
o-Azotoluene $(CH_3)C_6H_4N=NC_6H_4(CH_3)$	Mon.		C_{2h}^5	4		13.93	6.604 $\beta = 79°9'$	14.55	**1932**, 368.
2, 4, 6 Trinitrodiphenylamine $C_6H_5(NH)C_6H_2(NO_2)_3$	Mon.		C_{2h}^5	8	A	22.0	7.8 $\beta = 107°$	16.2	**1931**, 189.
Aniline Picrate $C_6H_5NH_2 \ldots (OH)C_6H_2(NO_2)_3$	Mon.		C_{2h}^5	4		13.2	7.4 $\beta = 93°$	15.2	**1931**, 189.
Ethyl Anisal p-Amino Cinnamate $C_{19}H_{16}NO_3$	Mon.		C_{2h}^5	4		6.65	7.88 $\beta = 135°35'$	45.6	**1933**, 40a.
p-Azoxyanisole* $C_{14}H_{14}N_2O_3$	Mon.		C_{2h}^5	4		11.0	8.10 $\beta = 107°30'$	14.95	**1933**, 40a; **1934**, 302.
p-Azoxyphenetole $C_{16}H_{18}N_2O_3$	Mon.		C_s^4	4		15.4	5.41 $\beta = 94°$	17.6	**1933**, 40a.
Dibenzylidenebenzidine	Mon.		C_{2h}^5	2	C_i	5.9	7.7 c sin $\beta = 21.5$ A		**1933**, 40a.
Dibenzyl $C_6H_5CH_2{-}CH_2C_6H_5$	Mon.	(*cm*)	C_{2h}^5	2	C_i	12.77	6.12 $\beta = 116°$	7.70	**1934**, 70, 227, 229.
Stilbene $C_6H_5CH=CHC_6H_5$	Mon.	(*cm*)	C_{2h}^5	4		12.20	5.72 $\beta = 113°48'$	16.00	**1933**, 364.

Tolane $C_6H_5C{\equiv}CC_6H_5$	Mon.	(cm)	4		12.80	5.68 $\beta=114°56'$	15.74	**1933**, 364.
p-Nitrostilbene $C_6H_5CH{=}CHC_6H_4(NO_2)$	Ort.		8		7.94	28.3	10.22	**1931**, 188.
p-Cyano-o-Nitro-p′-Methoxystilbene $C_6H_3(CN)(NO_2)CH{=}CHC_6H_4(OCH_3)$ (metastable yellow form)	Ort.	V_h^{19}, V^6 or C_{2v}^{11}	8		14.2	27.8	7.6	**1932**, 212.
p-Cyano-o-Nitro-p′-Methoxystilbene $C_6H_3(CN)(NO_2)CH{=}CHC_6H_4(OCH_3)$ (orange form)	Tri.		2		8.50	7.45 $\alpha=98°6'$, $\beta=106°20'$, $\gamma=75°40'$	13.35	**1932**, 212.
Stilbene+2 mol. 1, 3, 5 Trinitrobenzene $C_6H_5CH{=}CHC_6H_5\cdot 2[C_6H_3(NO_2)_3]$	Tri.		2		12.7	15.4 $\alpha=102°16'$, $\beta=85°30'$, $\gamma=87°35'$	7.7	**1931**, 192.
Diphenylbutadiene $C_6H_5CH{=}(CH)_2{=}CHC_6H_5$	Mon.	C_{2h}^1 or C_{2h}^2	4		7.71	11.70 $\beta=97°$	13.41	**1930**, 401.
Diphenylhexatriene $C_6H_5CH{=}(CH-CH)_2{=}CHC_6H_5$	Mon.	C_{2h}^5	2	C_i	6.63	7.43 $\beta=90°$	14.43	**1930**, 401.
Diphenyloctatetraene $C_6H_5(CH{=}CH)_4C_6H_5$	Mon.	C_{2h}^5	2	C_i	6.25	7.44 $\beta=90°$	16.03	**1930**, 401.
Diphenyldecapentaene $C_6H_5(CH{=}CH)_5C_6H_5$	Ort.	V_h^{15}	4	C_i	10.25	7.66	21.2	**1930**, 401.
Diphenyldodecahexaene $C_6H_5(CH{=}CH)_6C_6H_5$	Ort.		4		10.20	7.60	23.58	**1930**, 401.
Diphenyltetradecaheptaene $C_6H_5(CH{=}CH)_7C_6H_5$	Ort.		4		10.2	7.57	25.95	**1930**, 401.
Diphenyl Disulfide $(C_6H_5S)_2$	Ort.	V^4	4		23.5	8.21	5.63	**1932**, 137, 188.
Diphenyl Diselenide $(C_6H_5Se)_2$	Ort.	V^4	4		23.70	8.25	5.64	**1932**, 137, 188.

* In **1934**, 302, $a_o=16.0$ A, $b_o=8.08$ A, $c_o=20.5$ A, $\beta=107°30'$, C_{2h}^4, 8 mol.

Substance, symmetry and type		*Space group*	*No. mol. per cell*	*Min. mol. symmetry*	a_o	b_o	c_o	*References*
Dibenzyl Disulfide $(C_6H_5CH_2S)_2$	Mon.	C_{2h}^6 or C_s^1	4		13.46	8.23 $\beta=99°30'$	11.29	**1932**, 137.
Dibenzyl Diselenide $(C_6H_5CH_2Se)_2$	Mon.	C_{2h}^6 or C_s^1	4		13.50	8.17 $\beta=99°30'$	11.57	**1932**, 137.
Dibenzoyl Disulfide $(C_6H_5COS)_2$	Mon.	C_{2h}^5	4		12.26	12.00 $\beta=107°40'$	9.04	**1932**, 137.
Diphenyl Nitrosoamine $C_6H_5N—NO—C_6H_5$	Mon.	C_{2h}^3	16	A	17.08	8.867_5 $\beta=90°58'$	28.07	**1933**, 366.
Diphenyl $C_6H_5 \cdot C_6H_5$	Mon. (*aw*), (*cf*)							**1931**, 84, 354; **1932**, 129; **1933**, 359.
Diphenic Acid $(COOHC_6H_4)_2$	Ort.	V_h^{13}	8		13.80	11.90	14.12	**1931**, 84.
Hexachlorodiphenyl $(C_6H_2Cl_3)_2$	Ort.* (?)	V_h^{16}	8		15.80	8.54	21.48	**1931**, 84.
o-Tolidine $(C_6H_3CH_3NH_2)_2$	Ort.							**1931**, 84.
Naphthalene $C_{10}H_8$	Mon. (*bb*), (*cg*)	C_{2h}^5	2	C_i	8.29	5.97 $\beta=122°42'$	8.68	**1933**, 379.
1 Brom-2-Naphthylamine $C_{10}H_6Br(NH_2)$	Ort.		4		12.8	15.9	4.2	**1931**, 191.
4 Brom-1-Naphthylamine $C_{10}H_6Br(NH_2)$	Ort.		8		25.2	16	4.2	**1931**, 191.
4 Brom-1-Naphthylamine, 2, 6 Dinitrophenol (red form) $C_{10}H_6Br(NH_2)$, $C_6H_3OH(NO_2)_2$	Mon.	C_{2h}^5	4		9.5	13.5 $\beta=105°$	13.8	**1931**, 191.

4 Brom-1-Naphthylamine, 2, 6 Dinitrophenol (yellow form) $C_{10}H_6Br(NH_2)$, $C_6H_3OH(NO_2)_2$	Mon.		C_{2h}^5	4		14.0	8.0 $\beta=102°6'$	14.5	**1931**, 191.
1, 2 Naphthoquinone $C_{10}H_6O_2$	Mon.		C_s^2	2		3.84	8.10 $\beta=118°40'$	13.40	**1932**, 96.
1, 4 Naphthoquinone $C_{10}H_6O_2$	Mon.		C_{2h}^5	4		13.50	7.74 $\beta=121°10'$	8.25	**1932**, 96.
Naphthazarin (Alizarin Black)	Mon.		C_{2h}^5	2	C_i	3.85	8.02 $\beta=97°6'$	14.5	**1934**, 201.
Acenaphthene, Styphnic Acid $C_{10}H_6(CH_2)_2$, $C_6H(OH)_2(NO_2)_3$	Mon.			2		9.05	14.8 $\beta=99°$	6.8	**1932**, 412.
Anisal 1, 5 Diaminonaphthalene $C_{26}H_{22}O_2N_2$	Mon.		C_{2h}^5	4		21.7	12.7 $\beta=119°30'$	7.7	**1933**, 40a.
Anthracene $C_{14}H_{10}$	Mon.	(*bb*), (*ch*)	C_{2h}^5	2	C_i	8.58	6.02 $\beta=125°$	11.18	**1933**, 375, 376, 380.
Anthraquinone $C_{14}H_8O_2$	Ort.			8		19.7	24.5	3.95	**1930**, 405.
1, 2 Anthraquinone $C_{14}H_8O_2$	Mon.		C_{2h}^5	4		11.41	11.56 $\beta=130°30'$	9.30	**1932**, 96.
1, 4 Anthraquinone (tabular form) $C_{14}H_8O_2$	Mon.		C_s^2	2		4.19	5.81 $\beta=101°30'$	19.62	**1932**, 96.
1, 4 Anthraquinone (acicular form) $C_{14}H_8O_2$	Mon.		C_{2h}^2	4		13.82	9.54 $\beta=100°50'$	7.31	**1932**, 96.
2, 7 Dinitroanthraquinone $C_{14}H_6(NO_2)_2O_2$	Tet.			4		5.7		38.4	**1930**, 405.
2, 7 Dinitroanthraquinone Fluorene $C_{14}H_6(NO_2)_2O_2$, $(C_6H_4)_2CH_2$	Tri.			2		8.2 $\alpha=78°$, $\beta=82°$, $\gamma=$ca 80°	7.4	19.0	**1930**, 405.

* Optical examination makes this crystal monoclinic.

Substance, symmetry and type			Space group	No. mol. per cell	Min. mol. symmetry	a_o	b_o	c_o	References
Mesanthraquinone	Ort.		V^6	8		19.65	24.57	4.00	**1932**, 96.
p-Diphenylbenzene (Terphenyl) $C_6H_5(C_6H_4)C_6H_5$	Mon.	(*ci*)	C_{2h}^5	2	C_i	8.08	5.60 $\beta=91°55'$	13.59	**1933**, 292, 359, 360.
Chrysene $C_{18}H_{12}$	Mon.	(*cj*)	C_{2h}^6 or C_s^4	4		8.34	6.18 $\beta=115°48'$	25.0	**1933**, 214; **1934**, 117.
Quaterphenyl $C_6H_5(C_6H_4)_2C_6H_5$	Mon.	(*ci*)	C_{2h}^5	2	C_i	8.14	5.64 $\beta=97°$	18.4	**1933**, 187, 359.
Triphenylbenzene $C_6H_3(C_6H_5)_3$	Ort.	(*cn*)	C_{2v}^9	4		7.55	19.76	11.22	**1933**, 187; **1934**, 157, 194.
1, 2, 5, 6 Dibenzanthracene	Mon.		C_{2h}^2 or C_2^2	2		6.59	7.84 $\beta=103°30'$	14.17	**1933**, 214.
Dianthracene $(C_{14}H_{10})_2$	Ort.		V_h^{15}	4	C_i	8.18	12.15	18.75	**1932**, 207.
γ, γ′-Dibenzocarbazole	Mon.			4		14.05	12.02 $\beta=114°14'$	8.40	**1931**, 113.
Dimesityl	Mon.		C_{2h}^5	4		8.21	8.58 $\beta=96°30'$	22.25	**1930**, 59; **1931**, 84.
3, 3′-Diaminodimesityl	Mon.		C_{2h}^5	4		8.26	8.58 $\beta=90°$	22.62	**1930**, 59; **1931**, 84.

TABLE VII. PARAMETERS OF THE CARBON ATOMS IN DURENE

Atom	*No. per cell*	*x*	*y*	*z*
C(1)	4	0.188	0.314	0.267
C(2)	4	.093	.157	.127
C(3)	4	.037	−.005	.212
C(4)	4	−.055	−.162	.090
C(5)	4	−.108	−.325	.194

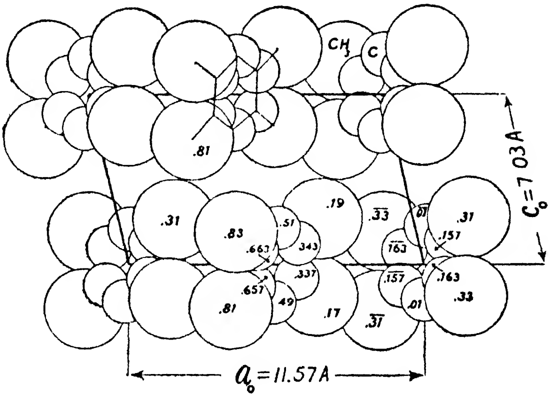


FIG. 336.—A projection upon the b-face of molecules in the monoclinic structure of durene, $C_6H_2(CH_3)_4$. The sizes given C and CH_3 in this drawing are without real significance.

All atoms are in general positions of C_{2h}^5 (not C_{2h}^4, as previously chosen): (e) $\pm(xyz)$; $\pm(x, \frac{1}{2}-y, z+\frac{1}{2})$. The x and z parameters are given in Table VIII.

TABLE VIII. PARAMETERS OF THE ATOMS IN C_6Cl_6

Atom	*x*	*z*	*Atom*	*x*	*z*
C(1)	0.181	0.026	Cl(1)	0.412	0.070
C(2)	.118	.087	Cl(2)	.278	.205
C(3)	.048	−.062	Cl(3)	.133	−.137

(*ce*) A structure has been proposed for **quinhydrone**, $C_6H_4O_2 \cdot C_6H_4(OH)_2$, which makes the oxygen atoms and hydroxyl groups equivalent. Though parameters have been published adequate data in support of them are lacking.

(*cf*) A partially described and tested structure has been suggested for **diphenyl**, $C_6H_5 \cdot C_6H_5$. No atomic coordinates have been published. The orientation of its molecule within the unit may be reproduced by rotating a planar $(C_6H_5)_2$ molecule having its center at a center of symmetry and its plane in bc. This rotation amounts to 32° about the c-axis and 20° about the b-axis.

(*cg*) A complete determination based upon quantitative intensity data and their Fourier analysis has been made of the atomic arrangement in **naphthalene**, $C_{10}H_8$. All atoms are in general positions of C_{2h}^5: (e) $\pm(xyz)$;

$\pm(x+\frac{1}{2}, \frac{1}{2}-y, z)$ with the parameters of Table IX. The molecules of this grouping pack together as shown in Figure 337. Atoms of neighboring molecules come within 3.60 A of one another.

TABLE IX. PARAMETERS OF THE ATOMS IN NAPHTHALENE

Atom	*x*	*y*	*z*
C(1)	0.087	0.014	0.328
C(2)	.114	.162	.217
C(3)	.047	.104	.035
C(4)	.074	.251	−.078
C(5)	.007	.193	−.260

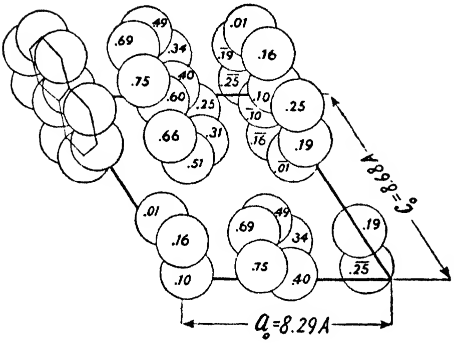


FIG. 337*a*.—(*left*) A projection of a portion of the monoclinic structure of naphthalene, $C_{10}H_8$, upon its b-face. The circles represent C atoms. Only parts of the molecules belonging to the bottom half of the cell are shown.

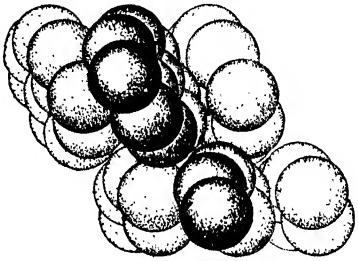
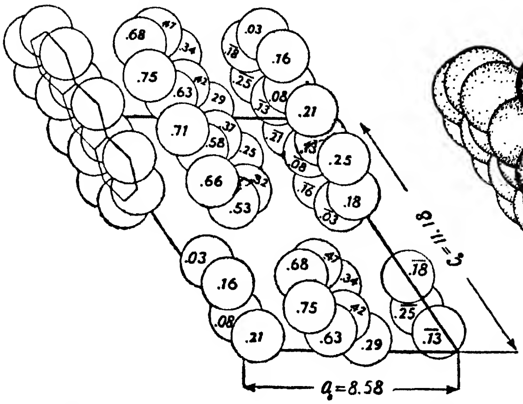


FIG. 337*b*.—(*right*) A packing drawing of *a* indicating the way the naphthalene molecules contact with one another.

(*ch*) The structure of **anthracene**, $C_{14}H_{10}$, also has been completely worked out from a series of spectrometer measurements and their Fourier analysis. Like naphthalene the atoms of its two-molecule monoclinic cell are in general positions of C_{2h}^5: (e) $\pm(xyz)$; $\pm(x+\frac{1}{2}, \frac{1}{2}-y, z)$. The parameters are those of Table X. The close similarity that exists between this anthracene arrangement (Figure 338) and the naphthalene grouping (Figure 337) may be most easily seen by comparing the two figures. In anthracene contacting molecules are slightly farther apart, the nearest intermolecular atomic separation being 3.77–3.80 A.

(*ci*) Another ring structure, established from quantitative data, is that of **p-diphenylbenzene**, $C_6H_5(C_6H_4)C_6H_5$. With its atoms also in general positions of C_{2h}^5: (e) $\pm(xyz)$; $\pm(x+\frac{1}{2}, \frac{1}{2}-y, z)$ (parameters in Table XI) this arrangement (Figure 339) is very similar to the two preceding. It



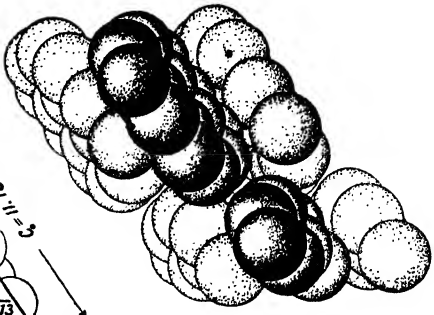


FIG. 338a.—(*left*) A portion of the monoclinic structure of anthracene, $C_{14}H_{10}$, projected on a b-face of its monoclinic unit. The close similarity between the arrangements found for naphthalene and anthracene may be seen by comparing Figures 337 and 338.

FIG. 338b.—(*right*) A packing drawing of *a*. In this and Figure 337*b* the radius chosen for the atomic spheres is that suggested by the closest approach of C atoms in adjacent molecules.

TABLE X. PARAMETERS OF THE ATOMS IN ANTHRACENE

Atom	*x*	*y*	*z*	*Atom*	*x*	*y*	*z*
C(1)	0.094	0.032	0.369	C(5)	0.033	0.130	−0.089
C(2)	.124	.157	.279	C(6)	.065	.254	−.179
C(3)	.062	.082	.140	C(7)	.002	.177	−.319
C(4)	.095	.207	.050				

TABLE XI. PARAMETERS OF THE ATOMS IN P-DIPHENYLBENZENE

Atom	*x*	*y*	*z*	*Atom*	*x*	*y*	*z*
C(1)	0.059	0.182	0.064	C(6)	−0.082	0.182	0.368
C(2)	−.046	0	.100	C(7)	−.187	0	.402
C(3)	−.105	−.182	.036	C(8)	−.246	−.182	.339
C(4)	−.094	0	.204	C(9)	−.200	−.182	.239
C(5)	−.036	.182	.268				

differs from them mainly in the fact that the long axes of its molecules are parallel to the ac-plane, whereas those of $C_{10}H_8$ and $C_{14}H_{10}$ are tilted at considerable angles.

Diphenyl, $C_6H_5 \cdot C_6H_5$, p-diphenylbenzene, $C_6H_5(C_6H_4)C_6H_5$, and quaterphenyl, $C_6H_5(C_6H_4)_2C_6H_5$, have nearly equal a_o and b_o axes and β angles. The molecules must therefore be similarly oriented in their crystals.

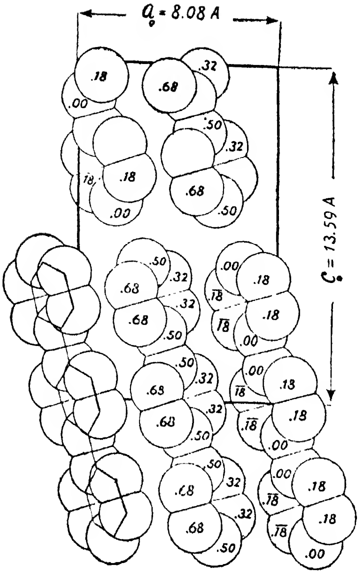


FIG. 339.—(*left*) A portion of the structure of p-diphenylbenzene, $C_6H_4(C_6H_5)_2$, projected on the b-face of its monoclinic unit. As in the figures immediately preceding circles represent C atoms. Only parts of the molecules associated with the upper half of the unit are included.

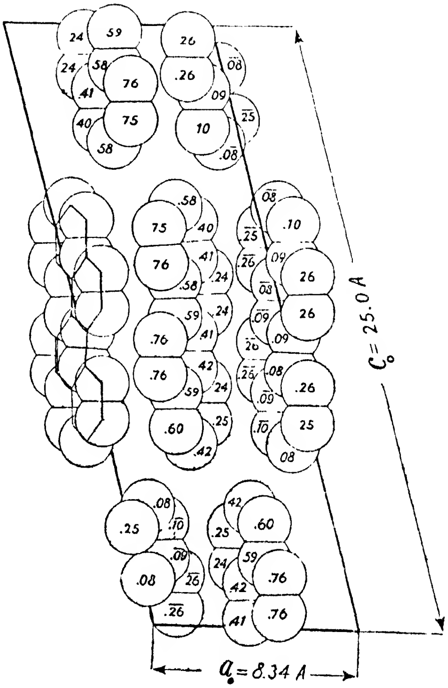
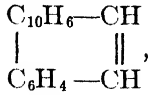


FIG. 340.—(*right*) A portion of the chrysene, $C_{18}H_{14}$, structure projected on its b-face. Only the molecules midway along the c-axis are fully shown.

TABLE XII. PARAMETERS OF THE ATOMS IN CHRYSENE

Atom	*No. per cell*	*x*	*y*	*z*
C(1)	8	−0.026	0.086	0.013
C(2)	8	.018	.084	.074
C(3)	8	−.036	.256	.100
C(4)	8	.010	.254	.161
C(5)	8	.108	.079	.196
C(6)	8	.161	−.095	.171
C(7)	8	.116	−.089	.110
C(8)	8	.170	−.262	.084
C(9)	8	.125	−.260	.023



(*cj*) **Chrysene,** $\begin{array}{l} C_{10}H_6\text{—}CH \\ |\qquad\quad \| \\ C_6H_4\text{—}CH \end{array}$, differs from the preceding aromatic hydrocarbons in having a four-molecule arrangement developed from C_{2h}^6. All atoms are in the general positions: (f) $\pm(xyz)$; $\pm(\bar{x}, y, \frac{1}{2}-z)$; $\pm(x+\frac{1}{2}, y+\frac{1}{2}, z+\frac{1}{2})$; $\pm(\frac{1}{2}-x, y+\frac{1}{2}, \bar{z})$. The parameters of Table XII, deduced from spectrometric measurements of intensity, lead to the symmetrical ring formula outlined in one of the molecules of Figure 340. Atoms of adjacent chrysene molecules come especially close to one another (ca 3.5 A).

(*ck*) It is said that there exists a 1:1 compound of 2, 4, 6 $C_6H_2Cl(NO_2)_3$ and 2, 4, 6 $C_6H_2CH_3(NO_2)_3$ which has cell dimensions identical with those of 2, 4, 6 $C_6H_2CH_3(NO_2)_3$.

(*cl*) It is interesting that styphnic acid, $C_6H(NO_2)_3(OH)_2$, and 2, 4, 6 trinitrophloroglucinol, $C(NO_2)_3(OH)_3$, which differ by an OH group, should have similar crystal structures.

(*cm*) It has been pointed out (**1933**, 364) that azobenzene, $C_6H_5N{=}NC_6H_5$, stilbene, $C_6H_5CH{=}CHC_6H_5$, and tolane, $C_6H_5C{\equiv}CC_6H_5$ have cells of nearly the same shape and size.

The unit of dibenzyl, $C_6H_5CH_2{-}CH_2C_6H_5$, differs only in having a c-axis reported to be half as long. Two structures have been proposed for this crystal. One of them gives a molecule that is almost planar. The molecule of the other has its two phenyl groups stepped with respect to one another but lying in parallel planes. Unfortunately the atomic parameters for the second arrangement have not been given.

(*cn*) From a preliminary study of **1, 3, 5 triphenylbenzene,** $C_6H_3(C_6H_5)_3$, it has been concluded that the molecular centers are in general positions of C_{2v}^9: (a) xyz; $\bar{x}, \bar{y}, z+\frac{1}{2}$; $x+\frac{1}{2}, \frac{1}{2}-y, z$; $\frac{1}{2}-x, y+\frac{1}{2}, z+\frac{1}{2}$ with $z=0$. Atomic parameters have not yet been found.

(*co*) A preliminary note, without a complete description of atomic positions, has recently been published on **p-quinone,** $C_6H_4O_2$.

Recent Aliphatic Structures

(*cp*) Laue and spectral photographs have been used to assign positions to the atoms in **oxalic acid dihydrate,** $(COOH)_2 \cdot 2H_2O$. The space group is C_{2h}^5 with two molecules per cell. Writing the coordinates of the general positions of this space group as (e) $\pm(xyz)$; $\pm(x+\frac{1}{2}, \frac{1}{2}-y, z+\frac{1}{2})$, the chosen atomic parameters are those of Table XIII. As can be seen from Figure 341, each water molecule is nearly equally distant (2.60–2.87 A) from three oxygen atoms. Within a molecule C-C = 1.59 A, C-O = 1.25 A; the angle between C-O bonds is 126°.

TABLE XIII. PARAMETERS OF THE ATOMS IN $(COOH)_2 \cdot 2H_2O$

Atom	*x*	*y*	*z*
C	−0.041	0.041	0.056
O(1)	.089	−.062	.150
O(2)	−.222	.222	.041
H_2O	−.444	−.375	.174

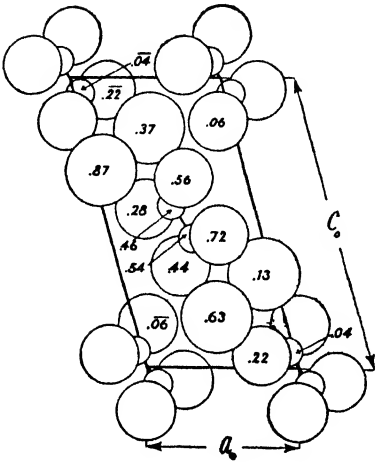


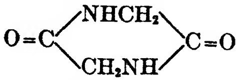
FIG. 341.—A b-face projection of the molecules of $H_2C_2O_4 \cdot 2H_2O$ associated with its monoclinic unit. The large circles are H_2O molecules. The O and OH of carboxyl groups, which are equivalent in this structure, are shown by the intermediate circles. The radii used in this figure were determined by convenience only.

(*cq*) A spectrometric study of **hexamethylenetetramine**, $C_6H_{12}N_4$, and a Fourier analysis of the intensities thus obtained are in complete agreement with one of the earlier investigations of this crystal. Carbon atoms are in (12a) v00; etc. [(*as*), book, p. 389], nitrogen in (8a) uuu; etc. with the same parameters: u=0.12, v=0.23.*

---

* On p. 390 of the book, values of u and v have been erroneously interchanged.

TABLE XIV. THE CRYSTAL STRUCTURES OF MISCELLANEOUS ORGANIC COMPOUNDS

Substance, symmetry and type		*Space group*	*No. mol. per cell*	*Min. mol. symmetry*	a_o	b_o	c_o	*References*
β-Polyoxymethylene	Hex.	C_3^2 or C_3^3			4.46		17.35	**1927**, 126; **1932**, 397, 406.
Eu-Polyethylene Oxide $(CH_2CH_2O)_x$(mol. wt. = ca 100,000)	Mon.	C_{2h}^4	36 (=x)		9.5	19.5 β = 101°	12.0	**1933**, 405.
Hexuronic Acid $C_6H_8O_6$	Mon.	C_2^2	4	A	17.71	6.32 β = 102°30′	6.38	**1932**, 116.
Diketopiperazine 	Mon.	C_{2h}^5	2	C_i	5.19	11.5 β = 83°	3.96	**1931**, 41.
$C_4H_2N_4O_3$ ON=CHCH=CN(NO)N=CO	Mon.		4		7.38	4.92 β = 105°34′	17.45	**1931**, 113.
Cyanuric Triazide $C_3N_3(N_3)_3$	Hex.		2		8.66		5.94	**1933**, 457; **1934**, 28.
Methylbixin $C_{26}H_{32}O_4$	Mon.	C_{2h}^5	4		10.56	13.40 β = 121°	20.62	**1930**, 402; **1932**, 458.
Choleic Acid*	Ort.				25.9	13.69	7.20	**1931**, 199.
Thiophene C_4H_4S	Tet. (*ar*)							**1930**, 45a.
Monomeric Butadiene Sulfone $C_4H_6SO_2$	Mon.	C_{2h}^5	4		9.55	11.35 β = 48°46′	6.23	**1932**, 398.
Monomeric Isoprene Sulfone $C_5H_8SO_2$	Mon.	C_2^2	2		6.60	7.62 β = 69°26′	6.67	**1932**, 398.

---

* If the formula of choleic acid is written as 8 $C_{24}H_{40}O_4$+1 mol. palmitic or stearic acid (cf. Wieland and Sorge), this cell contains only half a molecule.

Substance, symmetry and type	*Space group*	*No. mol. per cell*	*Min. mol. symmetry*	a_o	b_o	c_o	*References*
Monomeric Dimethyl Butadiene Sulfone $C_6H_{10}SO_2$ Ort.	V_h^{16}	4	C_s	7.55	12.12	7.39	1932, 398.
4 Isoxazolyl-5-Isoxazolyl Ketone $C_7H_4N_2O_3$ Mon.		16	A	15.31	14.75 $\beta=91°37'$	12.77	1931, 113.
3, 4 Bis (5 Methyl-3-Isoxazolylcarbonyl) Furazan-2-Oxide $C_{12}H_8N_4O_6$ Ort.		4		12.98	11.00	9.57	1931, 113.
5, 5 Diethyl Barbituric Acid (Veronal) $C_8H_{12}N_2O_3$ Ort.	V_h^{17}	4	C_2^v	7.11	14.4	9.7	1930, 404.
Veramon Ort. (Pyramidon, Veronal 1:1)	C_{2v}^2 or C_{2v}^4	4		27.1	12.2	7.20	1931, 187.
Pyramidon Tri.		4		7.4	18.1 α, β, γ not determined	10.8	1931, 187.
l-Ephedrine Hydrobromide Mon. $C_{10}H_{15}ON, HBr$	C_2^2	2		12.74	6.20 $\beta=100°48'$	7.62	1933, 155.
l-Ephedrine Hydrochloride Mon. $C_{10}H_{15}ON, HCl$	C_2^2	2		12.64	6.15 $\beta=102°6'$	7.34	1933, 155.
l-Ephedrine Hydroiodide Ort. $C_{10}H_{15}ON, HI$	V^3	12	A	25.66	7.33	19.14	1933, 155.
Racemic Ephedrine Hydrobromide $C_{10}H_{15}ON, HBr$ Mon.	C_{2h}^5	4		13.15	7.11 $\beta=119°25'$	14.00	1933, 154.
Racemic Ephedrine Hydrochloride $C_{10}H_{15}ON, HCl$ Mon.	C_{2h}^5	4		13.27	7.04 $\beta=118°24'$	13.44	1933, 154.
Racemic Ephedrine Hydroiodide $C_{10}H_{15}ON, HI$ Mon.	C_{2h}^5	4		13.40	7.23 $\beta=120°24'$	14.70	1933, 154.
d-Pseudoephedrine Hydrobromide $C_{10}H_{15}ON, HBr$ Ort.	V^4	4		24.68	6.93	6.78	1933, 155.

d-Pseudoephedrine Hydrochloride $C_{10}H_{15}ON, HCl$	Ort.	V^4	4		25.49	6.48	6.91	**1933**, 155.
d-Pseudoephedrine Hydroiodide $C_{10}H_{15}ON, HI$	Ort.	V^4	4		11.39	6.83	15.62	**1933**, 155.
Racemic Pseudoephedrine Hydrobromide $C_{10}H_{15}ON, HBr$	Mon.	C^5_{2h}	4		13.87	6.80 $\beta=116°51'$	14.04	**1933**, 154.
Racemic Pseudoephedrine Hydrochloride $C_{10}H_{15}ON, HCl$	Ort.	V^{15}_h	16	A	24.48	9.97	18.58	**1933**, 154.
Racemic Pseudoephedrine Hydroiodide $C_{10}H_{16}ON, HI$	Mon.	C^5_{2h}	4		13.49	6.97 $\beta=114°26'$	14.62	**1933**, 154.
d-Pseudococaine-l-Ephedrine-d-Tartrate Monohydrate $C_{31}H_{42}O_{11}N_2 \cdot H_2O$	Mon.		2		18.90	9.92 $\beta=107°21'$	9.36	**1932**, 82.
d-Pseudococaine-l-Methyl Ephedrine-d-Tartrate Dihydrate $C_{32}H_{44}O_{11}N_2 \cdot 2H_2O$	Mon.		2		19.62	9.76 $\beta=98°42'$	9.61	**1932**, 82.
l-Methyl Ephedrine Hydrobromide $C_{11}H_{17}ON, HBr$	Ort.	V^4	4		17.30	7.36	9.64	**1934**, 330.
l-Methyl Ephedrine Hydrochloride $C_{11}H_{17}ON, HCl$	Ort.	V^4	4		16.90	7.22	9.66	**1934**, 330.
l-Methyl Ephedrine Hydroiodide $C_{11}H_{17}ON, HI$	Ort.	V^3	8		6.10	31.60	13.25	**1934**, 330.
Racemic Methyl Ephedrine Hydrobromide (1st mod.) $C_{11}H_{17}ON, HBr$	Mon.	C^5_{2h}	4		17.28	7.30 $\beta=102°28'$	10.16	**1934**, 330.
Racemic Methyl Ephedrine Hydrobromide (2nd mod.) $C_{11}H_{17}ON, HBr$	Mon.	C^5_{2h}	4		5.83	30.78 $\beta=107°8'$	7.02	**1934**, 330.
Racemic Methyl Ephedrine Hydrochloride $C_{11}H_{17}ON, HCl$	Mon.	C^5_{2h}	4		17.15	7.08 $\beta=101°30'$	10.01	**1934**, 330.
Racemic Methyl Ephedrine Hydroiodide $C_{11}H_{17}ON, HI$	Tri.		2		11.2	7.67 $\alpha=108°55', \beta=95°36', \gamma=84°15'$	7.68	**1934**, 330.

Substance, symmetry and type		*Space group*	*No. mol. per cell*	*Min. mol. symmetry*	a_o	b_o	c_o	*References*
Cholesteryl Bromide	Mon.	C_2^2	2		10.7	7.45 $\beta=132°$	21.4	**1933**, 40a.
Cholesteryl Chloride	Mon.	C_2^2	2		10.3	7.0 $\beta=131°$	21.2	**1933**, 40a.
Cholesteryl Salicylate $C_{34}H_{50}O_3$	Tri.	C_1^1	1		9.68 $\alpha=85°53'$,	12.52 $\beta=77°41'$,	6.31 $\gamma=84°1'$	**1934**, 334.
Ergosterol $C_{27}H_{41}OH$	Mon.	C_2^2	4	A	9.75	7.4 $\beta=65°$	39.1	**1932**, 39.
Lumisterol $C_{27}H_{41}OH$	Mon.	C_2^2	4	A	20.3	7.25 $\beta=60°$	20.4	**1932**, 39.
Calciferol $C_{27}H_{41}OH$	Mon.	C_2^2	8	A	20.8	7.15 $\beta=68°$	38.5	**1932**, 39.
Calciferol Pyrocalciferol (1:1)	Mon.	C_2^3	4		20.2	7.35 $\beta=63°$	40.0	**1932**, 39.
Pregnandiol	Ort.				10.2	7.3	24.6	**1932**, 38.
α-Dihydroergosterol, Ethyl Alcoholate $C_{27}H_{43}OH$, C_2H_5OH	Mon.	C_2^3	12	A	30.8	7.4 $\beta=53°$	43.1	**1932**, 39.
Ketohydroxyoestrin	Mon.	C_2^2	4	A	7.5	22.1 $\beta=112°$	9.06	**1932**, 37, 38. **1934**, 343.
α-Follicular Hormone (unstable rhombic form) $C_{18}H_{22}O_2$	Ort.		4		7.84	10.0	18.2	**1934**, 343.
α-Follicular Hormone (stable rhombic form) $C_{18}H_{22}O_2$	Ort.		4		12.0	16.2	7.45	**1934**, 343.
α-Follicular Hormone Monohydrate $C_{18}H_{24}O_3$	Mon.		4		22.85	7.55 $\beta=70\frac{1}{2}°$	9.15	**1934**, 343.
Trihydroxyoestrin	Mon.	C_2^2	4	A	7.50	22.8 $\beta=112°$	9.06	**1932**, 37.

(Lactone 135) $C_{23}H_{36}O_2$	Mon.	C_2^2	2		10.6	7.7 $\beta=79°$	11.7	**1934**, 18.
Dianhydrogitoxigenin $C_{23}H_{29}O_2(OH)$	Mon.	C_2^2	2		9.62	7.85 $\beta=86\frac{1}{2}°$	12.8	**1934**, 18.
Digitoxigenin $C_{23}H_{32}O_2(OH)_2$	Ort.	V^4	4		18.13	7.16	14.95	**1934**, 18.
Gitoxigenin $C_{23}H_{31}O_2(OH)_3$	Mon.	C_2^3	8	A	6.16	13.3 $\beta=82°$	53.3	**1934**, 18.
Digoxigenin $C_{23}H_{31}O_2(OH)_3$	Ort.	V^4	4		9.62	16.75	12.85	**1934**, 18.
Vitamin B_1 Hydrochloride $C_{12}H_{18}O_2N_4S$, 2HCl (Windaus)	Mon.	C_{2h}^5	4		12.62	20.53 $\beta=66°5'$	6.96	**1933**, 39.
Adenine Hydrochloride*	Mon.	C_{2h}^4 or C_s^2			8.71	4.80 $\beta=62°0'$	20.00	**1933**, 39.
Insulin†	Mon.		26		130	100 $\beta=$ca 90°	80	**1932**, 105.
Pepsin	Hex.				67		154	**1934**, 17.

* The unit cell as stated above contains 4 hydrochloride and 2 H_2O molecules. Crystals of a supposed vitamin B_4 have an almost identical cell; it is concluded therefore that the B_4 is only an impurity in this adenine hydrochloride.

† From the published data it is certain that this cell cannot be the true unit.

Appendix

Bibliography of Crystal Structure Data

This bibliography continues that published as an appendix to the second edition of "The Structure of Crystals." In adding items through 1930, papers by authors who already appear have been given existing numbers with an added a, b, etc.; articles by new authors have been arranged alphabetically with new numbers. The same procedure has been followed in numbering very recent additions to the lists for subsequent years.

Year 1925

281. Meisel, K. Dissertation, Hannover.

Year 1927

313. Shinoda, G. X-ray Analysis of Cast Alloys II. Bronze, *Suiyokaishi* **5**, 472.

Year 1928

253a. Menzer, G. Crystal Lattice of Eulytite, *Centr. Mineral. Geol.* **1928A**, 420.

451. Sarkar, A. N. X-ray Examination of the Crystal Structure of Resorcinol, *Proc. 15th Indian Sci. Cong.* **1928**, 92.

Year 1929

205a. Machatschki, F. Algodonite and Whitneyite, *Neues Jahrb. Mineral. Geol. Beilage-Bd.* **59A**, 137. **205b.** X-ray Examination of Remelted Algodonite and Whitneyite. Supplement, *Centr. Mineral. Geol.* **1929A**, 371.

289a. Schiebold, E. Crystal Structure of Feldspars, *Fortschr. Min. Krist. Pet.* **14**, 62.

381. Barth, T. F. W. The Symmetry of Potash Feldspar, *Fortschr. Min. Krist. Pet.* **13**, 31. (See also *Centr. Mineral. Geol.* **1928A**, 380).

382. Eulitz, W. An Auxiliary Apparatus for the Orientation of Small Crystals for X-ray Investigation, *Z. Krist.* **70**, 506.

383. Nakamoto, M. and Sano, G. Water Content of Inorganic Compounds I. Water Content of Acid Clay of Koto, *J. Chem. Soc. Japan* **50**, 473.

384. Schiebold, E. and Reininger, H. X-ray Structure Investigations, *Giesserei-Ztg.* **26**, 634, 666.

Year 1930

3a. Ageev, N. and Sachs, G. The X-ray Determination of the Solubility of Copper in Silver, *Mitt. deut. Materialprüfungsanstalt* **13**, 50.

19a. Bragg, W. H. Cellulose in the Light of X-rays, *Cellulose* **1**, 80, 110; *Nature* **125**, 315.

22a. Bragg, W. L. Structure of Silicates, *J. Soc. Glass Tech.* **14**, 295.

38a. Brill, R. X-ray Determination of the Form and Boundary Surfaces of Submicroscopic Crystals, *Z. Krist.* **75**, 217.

44a. Brukl, A. and Ortner, G. The Sulfides of Gallium, *Sitzungsber. Akad. Wiss. Wien, Math.-naturw. Kl. Abt. IIb,* **139**, 594.

45a. Bruni, G. and Natta, G. The Crystal Structure of Benzene and its Relation to that of Thiophene II, *Rendiconti accad. Lincei* **11**, 1058.

49a. Busse, W. Dependence of the Width and Intensity of Debye Lines and Rings on the Dimensions of the X-ray Source, of the Preparation and of the Camera, *Z. Physik* **66**, 285.

Year 1930

69a. Debye, P. Interferometric Determination of the Structure of Individual Molecules, *Z. Elektrochem.* 36, 612.

72a. Dehlinger, U. X-ray Investigation of the System Cadmium-Magnesium, *Z. anorg. Chem.* 194, 223.

74a. Desmaroux and Mathieu. X-ray Study of the Gelatinization of Nitrocellulose, *Compt. rend.* 191, 786.

97a. Friauf, J. B. The Application of X-rays to the Study of Metals, *Rev. Sci. Instruments* 1, 361.

105a. Gossner, B. Eudialyte, *Centr. Mineral. Geol.* 1930A, 449. **105b.** Boleite, Pseudoboleite and Cumengeite, *Z. Krist.* 75, 365.

111b. Gossner, B. and Mussgnug, F. Alstonite and Milarite—a Contribution to the Study of Complex Crystals, *Centr. Mineral. Geol.* 1930A, 220. **111c.** Barytocalcite and its Structural Relations to Other Materials, *ibid.* 1930A, 321. **111d.** Crystallographic Relationships between Epidote and Zoisite, *ibid.* 1930A, 369.

116a. Hägg, G. Crystal Structure of the Compound Fe_2B, *Z. physik. Chem.* 11B, 152.

119a. Halla, F. and Mehl, E. Fiber Structure of Plastic Sulfur, *Sitzung Akad. Wiss. Wien. Math.-naturw. Kl. 15 Mai* 1930, *Akad. Anzeiger* No. 13.

122a. Hassel, O. and Kringstad, H. The Structure of the Cyclohexane Molecule, *Tids. Kemi Bergvaesen* 10, 128.

154a. Jaeger, F. M. Natural and Artificial Ultramarines, *Bull. soc. franç. min.* 53, 183.

179a. Krishnamurti, P. Studies in X-ray Diffraction II. Some Colloidal Solutions and Liquid Mixtures, *Indian J. Physics* 5, 489. **179b.** III. Some Aromatic Hydrocarbons in the Solid and Liquid States, *ibid.* 5, 543.

184a. Laves, F. Elementary Regions, *Z. Krist.* 76, 277.

191a. McFarlan, R. L. X-ray Study of Molecular Orientation in the Kerr Effect, *Phys. Rev.* 35, 211.

193a. Machatschki, F. The General Formula of Vesuvianite and its Relation to Garnet, *Centr. Mineral. Geol.* 1930A, 284. **193b.** The Formula of Eucolite, *ibid.* 1930A, 360. **193c.** Chemistry of Crystals and Silicates, *Forschungen u. Fortschritte* 1930, 418.

194a. Mahadevan, C. X-ray Study of Vitrains, *Indian J. Physics* 5, 525.

197a. Mark, H. The Use of X-rays in the Study of Polysaccharides and their Derivatives, *Dixième Conférence de l'Union Internationale de Chimie* (*Liège 13-21 Septembre* 1930). *Rapport présenté à la Session Scientifique*, p. 175.

218a. Natta, G. Structure of Silicon Tetrafluoride, *Gazz. chim. ital.* 60, 911.

220a. Natta, G. and Nasini, A. The Structure of the Inert Gases I. Xenon, *Rendiconti accad. Lincei* 11, 1009.

225a. Niggli, P. Stereochemistry of Crystal Compounds IV. Interatomic Distances in Crystals, *Z. Krist.* 76, 235.

234a. Onorato, E. New application of the Laue Method, *Neues Jahrb. Mineral. Geol., Referate I*, 168 (1932).

237a. Ôsawa, A. Effect of Absorbed Hydrogen on the Lattice Constant of Palladium-Silver Alloys, *Kinzoku-no-Kenkyu* (*J. Study of Metals*) 7, 243.

246a. Passerini, L. Solid Solutions, Isomorphism and Symmorphism of the Oxides of Bivalent Metals III. The Systems: MnO-CdO; MnO-MgO, *Gazz. chim. ital.* 60, 535. **246b.** Solid Solutions, Isomorphism and Symmorphism of the Oxides of Trivalent Metals. The Systems: Al_2O_3-Cr_2O_3; Al_2O_3-Fe_2O_3; Cr_2O_3-Fe_2O_3, *ibid.* 60, 544. **246c.** Spinels III. The Titanates of Cobalt and of Zinc, *ibid.* 60, 957.

247a. Pastorello, S. Thermal Analysis of the System: Lithium-Copper, *Gazz. chim. ital.* 60, 988.

259a. Pauling, L. The Determination of Crystal Structure by X-rays, *Ann. Survey of Amer. Chem.* 5, 118 (1929-30).

264a. Polansky, V. S. Literature on the Use of the X-ray II, *Heat Treating and Forging* 16, 1011.

287a. Schmid, E. and Wassermann, G. X-ray Studies on the Tempering Problem I, *Metallwirtschaft* 9, 421. **287b.** The Texture of Drawn Magnesium and Zinc Wires, *Mitt. deut. Materialprüfungsanstalt Sonderheft* 10, 87.

290a. Seemann, H. Optics of X-ray Reflection from Crystals V. Wide Angle Diagrams, *Ann. Physik* 7, 633.

304a. Stewart, G. W. Two Different Types of Association of Alcohol Molecules in the Liquid State, *Phys. Rev.* 35, 296. **304b.** Effect of Electric Field upon X-ray Diffraction Pattern of a Liquid, *ibid.* 36, 1413.

324a. Trillat, J. J. The Constitution of the Ordinary and Film Forms of Cellulose Nitrates and Acetates, *J. phys. radium* 1, 340. **324b.** Phenomena of the Transformations of the Space Lattice of Nitrocellulose. Their Generality in Cellulose Compounds, *Compt. rend.* 191, 1441.

340a. Wever, F. and Möller, H. The Crystal Structure of Iron Silicide, FeSi, *Z. Krist.* 75, 362.

351a. Wyart, J. The Dehydration of Heulandite Studied by Means of X-rays, *Compt. rend.* 191, 1343.

368. Adati, K. and Miyaki, K. X-ray Intensimeter, *Electro-Tech. Lab. Tokyo Circ.* No. 70.

369. Adinolfi, E. The Lattice Distance and the Reflecting Power for X-rays of Bismuth Relative to the Cleavage Planes, *Rend. accad. sci. Napoli* 36, 69.

370. Alcâcer, J. N. Cold Working and Annealing of α-Brass, *Anales soc. españ. fís. quím.* 28, 1420.

371. Alsen, N. Crystal Structure of Covellite (CuS) and Copper Glance (Cu$_2$S), *Geol. Fören. Förh.* 53, 111 (1931).

372. Andress, K. and Reinhardt, L. Swelling of Cellulose in Perchloric Acid, *Z. physik. Chem.* 151A, 425.

373. Barrett, C. S. X-ray Fiber Structure of Alloys Containing Precipitated Crystals, *Phys. Rev.* 35, 1425.

374. Baumgaertel, K. Investigations on the Influence of Covered Welding Electrodes on the Mechanical Properties of the Welds, *Forschungsarbeiten Geb. Ingenieurw.* No. 336; *Metals and Alloys* 2, *Abstr.* 70.

375. Bergquist, O. The Grating Constant of Quartz, *Z. Physik* 66, 494.

376. Blake, F. C. An Interesting Case of a Unit Lattice Made up of Interpenetrating Lattices, *Phys. Rev.* 35, 660.

377. Bouchonnet, Jacquet and Mathieu. Action of Acids on Cellulose, *Bull. soc. chim. France* 47, 1265.

378. Cardoso, G. M. Modern X-ray Methods Applied to the Determination of the Crystal Structure of Epsomite, *Trabajos del Museo Nac. de Ciencias Nat., Ser. Geol.* No. 37.

379. Chikashige, M. and Yamamoto, T. The Crystal Structures of the Compounds formed in the Antimony-Cadmium System, *Anniv. Vol. Dedicated to Masumi Chikashige* (*Kyoto Imp. Univ.*) 1930, 195.

380. Claus, W. D. Temperature Effect in Diffuse Scattering of X-rays from Rock Salt, *Phys. Rev.* 35, 1427.

381. Clouse, J. H. The Crystal Structure of Calcium Chromate, *Z. Krist.* 76, 285.

382. Debińska, Z. The Crystalline Structure of Cathodic Deposits, *Bull. intern. acad. polonaise* 1930A, 460.

383. Dupré la Tour, F. The Polymorphism of the Saturated Diacids of the Aliphatic Series as a Function of Temperature, *Compt. rend.* 191, 1348.

384. Edwards, R. L. and Stewart, G. W. Dependence of Viscosity in Liquids upon the Molecular Space Arrangement as Shown by X-ray Diffraction, *Phys. Rev.* 35, 291.

385. Erdmannsdörffer, O. H. Halloysite from Elbingerode [Harz], *Chem. Erde* 5, 96.

386. Fermi, E. The Calculation of the Spectra of Ions, *Mem. accad. Italia, Cl. sci. fis. mat. nat.* 1, No. 2.

387. Ferrari, A. The Structure of Matter in the Solid State, *Scientia, Dec.* 1930, p. 131.

388. Friauf, J. B. and Gensamer, M. Crystal Structure of the Alloys of Iron and Manganese, *Mining Met. Investig. U. S. Bur. Mines, Carnegie Inst. Tech., Mining Met. Advisory Boards 4th Open Meeting of the Met. Board Oct. 17,* 1930.

389. Frost, A. V. X-ray Study of the Crystalline Structure of Violet Phosphorus, *J. Russ. Phys.-Chem. Soc.* 62, *Chem. Pt.* 2235.

390. Fujiwara, T. Spectral Lines Obtained by the Method of Convergent X-rays, *Mem. Coll. Sci. Kyoto Imp. Univ.* 13A, 303.

391. v. Gaertner, H. R. The Crystal Structure of Loparite and Pyrochlore, *Neues Jahrb. Mineral. Geol. Beilage-Bd.* 61A, 1.

392. Gerngross, O., Triangi, O. and Koeppe, P. Thermal Disaggregation of Gelatin (X-ray Study of its Degradation), *Ber.* 63B, 1603.

Year 1930

393. **v. Göler and Sachs, G.** The Refining of an Aluminum Alloy as Seen in the X-ray Photograph, *Mitt. deut. Materialprüfungsanstalt Sonderheft* 10, 33. 394. Rolling and Recrystallization Structure of Regularly Surface-centered Metals III, IV, V, *ibid. Sonderheft* 10, 90, 94, 98. 395. Tensile Tests on Crystals of Copper and α-Brass, *ibid. Sonderheft* 10, 108.

396. **Gottfried, C.** X-ray Investigations of Liquids and Glasses, *Glastech. Ber.* 8, 401.

397. **Grebe, L.** Determination of Crystallite by Means of X-rays, *Z. tech. Physik* 11, 428.

398. **Halla, F.** X-ray Distinctions between Magnesite and Dolomite, *Sitzungsber. Akad. Wiss. Wien, Math.-naturw. Kl. Abt. IIb*, 139, 683; *Monatshefte Chem.* 57, 1.

399. **Haraldsen, H.** The Thermal Transformation of Talc, *Neues Jahrb. Mineral. Geol. Beilage-Bd.* 61A, 139.

400. **Heinz, H.** Origin, Weathering and Artificial Coloring of Agate, *Chem. Erde* 4, 501.

401. **Hengstenberg, J. and Kuhn, R.** The Crystal Structure of the Diphenylpolyenes, *Z. Krist.* 75, 301. 402. A Determination of the Molecular Weight of Methylbixin by Means of X-rays, *ibid.* 76, 174.

404. **Hertel, E.** Addition Centers as Coordination Centers. The Crystal Structure of Veronal, *Z. physik. Chem.* 11B, 279.

405. **Hertel, E. and Römer, G. H.** The Structure of Quinoid Compounds and of a Molecular Compound of the Quinhydrone Type, *Z. physik. Chem.* 11B, 90.

406. **Herzog, R. O. and Kratky, O.** Geometric System of Molecules Having Periodicity of Building Groups, *Naturwiss.* 18, 732.

407. **Hirata, H., Komatsubara, H. and Tanaka, Y.** The Arrangement of the Microcrystals in White Tin Deposited by Electrolysis, *Anniv. Vol. Dedicated to Masumi Chikashige (Kyoto Imp. Univ.)* 1930, 261.

408. **Honda, K. and Kokubo, S.** Age-hardening Mechanism in Aluminum Copper Alloys, *Congr. intern. Mines, mét. géol. appliquée, Sect. Mét. 6th session, Liège, June* 1930, 621; *Metals and Alloys* 3, *Abstr.* 42.

409. **Katz, J. R. and Selman, J.** Influence of the Form and Polarity of Molecules on the X-ray Spectrum of Liquids III. The Appearance of Two Amorphous Rings in Substances Whose Molecules Are Probably Disk-shaped, *Z. Physik* 66, 834.

410. **Katz, J. R., Derksen, J. C., Kramers, C. A., Hess, K. and Trogus, C.**, Structure of Celluloid and Nitrocellulose and the Gelatinizing Medium of Nitrocellulose as a Swelling Medium II. X-ray Spectrograms of Camphor Celluloid with Varying Camphor Content, *Z. physik. Chem.* 151A, 145.

411 **Katz, J. R., Derksen, J. C., Hess, K. and Trogus, C.** Structure of Celluloid and Nitrocellulose and the Gelatinizing Medium of Nitrocellulose as a Swelling Medium III. Celluloids with Other Cyclic Ketones as Jelling Media, *Z. physik. Chem.* 151A, 163. 412. IV. Acid Amides and Esters as Jelling Media, *ibid.* 151A, 172.

413. **Kerr, P. F.** Kaolinite from a Brooklyn Subway Tunnel, *Am. Mineral.* 15, 144.

414. **Kidani, Y.** Crystallographic Investigation of Some Mechanical Properties of Metals I, *J. Faculty Eng. Tokyo Imp. Univ.* 19, 1. 415. II, *ibid.* 19, 7.

416. **Korsunskii, M.** Diffraction of X-rays in Liquids, *Uspekhi Fiz. Nauk* 10, 719.

417. **Kratky, O.** An X-ray Goniometer for Research on Polycrystals, *Z. Krist.* 72, 529. 418. X-ray Examination of Microscopic Crystals I, *ibid.* 73, 567. 419. II. The Micro Convergence Method, *ibid.* 76, 261.

420. **Lennard-Jones, J. E.** The Dependence of Crystal Spacing on Crystal Size, *Z. Krist*, 75, 215.

421. **Leonhardt, J.** The X-ray Method of Investigating Structure and Texture and its Application to Potassium-salt Deposits, together with a Report on the Structure of Carnallite, *Kali* 24, 226, 245, 264, 277.

422. **Mark, H. and Meyer, K. H.** Construction of the Crystalline Part of Cellulose II, *Cellulosechemie* 11, 91.

423. **Mauguin, C.** The Unit Cell of Chlorite, *Bull. soc. franç. mineral.* 53, 279.

424. **McLennan, J. C. and McKay, R. W.** Crystal Structure of Uranium, *Trans. Roy. Soc. Can.* 24, *Sect.* 3, 1. 425. Crystal Structure of Metallic Lanthanum, *ibid.* 24, *Sect.* 3, 33.

426. **Mehmel, M.** The Structure of Apatite I, *Z. Krist.* 75, 323.

Year 1930

427. **Miles, F. D. and Craik, J.** The Structure of Nitrated Cellulose II. The X-ray Examination of Nitroramie, *J. Phys. Chem.* 34, 2607.

428. **Nasini, A. and Natta, G.** The Crystal Structure of the Inert Gases II. Krypton, *Rendiconti accad. Lincei* 12, 141.

429. **Natta, G. and Casazza, E.** The Structure of Hydrogen Phosphide and of Hydrogen Arsenide, *Gazz. chim. ital.* 60, 851.

430. **Nix, F. C. and Schmid, E.** The Casting Texture of Metals and Alloys, *Mitt. deut. Materialprüfungsanstalt Sonderheft* 10, 79.

431. **Noll, W.** Nontronite, *Chem. Erde* 5, 373.

432. **Nusbaum, C.** Radial-asterism in Multi-crystalline Materials, *Phys. Rev.* 35, 1426.

433. **Parravano, N.** Blanc's Alumina, *Mem. accad. Italia, Cl. sci. fis. mat. nat.* 1, *Chim.* No. 1.

434. **Parravano, N. and Caglioti, V.** Investigation of the System: Bismuth-Selenium, *Gazz. chim. ital.* 60, 923.

435. **Parravano, N. and Montoro, V.** Alloys of Zinc and Manganese, *Met. ital.* 22, 1043.

436. **Pesce, B.** X-ray Investigations of Potassium Fluoborate., *Gazz. chim. ital.* 60, 936.

437. **Raaz, F.** The Crystal Structure of Gehlenite, *Akad. Anzeiger Wien* No. 15, 136; No. 18, 203; *Neues Jahrb. Mineral. Geol.* 1931, I, 190. 438. The Fine Structure of Gehlenite. A Contribution to the Knowledge of Melilite, *Sitzungsber. Akad. Wiss. Wien Abt. I,* 139, 645.

439. **Roberts, O. L.** X-ray Study of Very Pure Iron, *Phys. Rev.* 35, 1426.

440. **Sakisaka, Y.** Reflection of Monochromatic X-rays from Some Crystals, *Proc. Phys.-Math. Soc. Japan 3rd Ser.* 12, 189.

441. **Scherrer, P. and Staub, H.** X-ray Investigation of the Coagulation Process of Colloidal Gold, *Helv. Phys. Acta* 3, 457.

442. **Schachtschabel, P.** Dehydration and Rehydration of Kaolin, *Chem. Erde* 4, 395.

443. **Schoep, A.** Stainierite and a New Deposit of This Mineral, *Ann. serv. mines comité spécial Katanga, Brussels* 1, 55; *Rev. géol.* 11, 499.

444. **Schoep, A. and Cuvelier, V.** Stainierite (Cobaltic Hydroxide), a New Mineral, *Bull. soc. belg. géol. pal. hydrol.* 39, 74.

445. **Shubnikov, L. V. and de Haas, W. J.** Preparation and Investigation of Bismuth Crystals, *J. Russ. Phys.-Chem. Soc.* 62, *Phys. Pt.* 529.

445a. **Sims, H. des B. and Scott, D. A.** Spectoscopic Properties of Insulin, *Trans. Roy. Soc. Can.* 24, *Sect.* 5, 117.

446. **Sjöman, P.** An X-ray Investigation of the Decomposition Ratio in the System Iron Oxide-Silicic Acid, *Tekniska Samfundets Handl.* 1930, No. 7.

447. **Skinner, E. W.** Diffraction of X-rays in Liquids; Effect of Temperature, *Phys. Rev.* 36, 1625.

448. **Sponsler, O. L. and Dore, W. H.** Structure of Ramie Cellulose as Deduced from X-rays, *Cellulosechemie* 11, 186.

449. **Struve, K.** Application of Born's Theory of the Crystal Lattice to the Calculation of the Physical Parameters of α-Quartz, *J. Russ. Phys.-Chem. Soc.* 62, *Phys. Pt.* 563.

450. **Thibaud, J. and Trillat, J. J.** Scattering of X-rays by Liquids and Various Substances. Influence of Filtering the White Radiation. Absorption Coefficients of Liquid Fatty Acids, *Z. Physik* 61, 816.

451. **Vaidyanathan, V. I.** X-ray Diffraction in Heated Liquids and in Solutions, *Indian J. Physics* 5, 501.

452. **Wagner, C. and Schottky, W.** Theory of Arranged Mixed Phases. *Z. physik. Chem.* 11B, 163.

453. **de Weerd, L.** Orientation of Fibers in a Sheet of Paper, *Chem. Weekblad* 30, 46.

454. **Westgren, A. and Ekman, W.** Structure Analogies of Intermetallic Phases, *Arkiv. Kemi Mineral. Geol.* 10B, No. 11, 1.

455. **Westgren, A. and Phragmen, G.** System: Chromium-Carbon, *Z. anorg. Chem.* 187, 401.

456. **Wever, F. and Jellinghaus, W.** The Two-component System: Iron-Vanadium, *Mitt. Kaiser Wilhelm-Inst. Eisenforsch. Düsseldorf* 12, 317.

Year 1930

457. **Zambonini, F. and Ferrari, A.** Identity of Crystalline Structure of Cancrinite of Monte Somma with that of Mias (Urals), *Rendiconti accad. Lincei* 11, 782.

458. **Zschacke, F. H.** Mercury Glasses, *Glastech. Ber.* 8, 519.

Year 1931

1. **Aanerud, K.** The Formation of Mixed Crystals in the Scheelite Group by Precipitation from Solutions, *Norske Videnskaps-Akad. Oslo I, Mat. naturv. Kl.* 1931, No. 13, 1.

2. **Achenbach, H.** Thermal Decomposition of Synthetic Hydrargillite (Gibbsite), *Chem. Erde* 6, 307.

3. **Agte, C., Alterthum, H., Becker, K., Heyne, G. and Moers, K.** The Physical Properties of Rhenium, *Naturwiss.* 19, 108. 4. Physical and Chemical Properties of Rhenium, *Z. anorg. Chem.* 196, 129.

5. **Akkarov, V.** X-ray Apparatus for Structure Determination, *J. Tech. Phys. (U.S.S.R.)* 1, 498.

6. **Albrecht, W. H. and Wedekind, E.** Distinguishing the Different Types of Ferric Oxides and Hydrated Oxides by Their Characteristic Properties III, *Z. anorg. Chem.* 202, 205. 7. IV, *ibid.* 202, 209.

8. **Alichanov, A. I.** The X-ray Examination of Aluminum at High Temperatures, *J. Applied Phys. (U.S.S.R.)* 6, 19; *Metals and Alloys* 3, *Abstr.* 285.

9. **Aminoff, G.** Lattice Dimensions and Space Group of Braunite, *Kungl. Svenska Vetenskapsakad. Handl. III*, 9, No. 5, 14. 10. (with chemical analyses by R. Blix) Arsenoklasite, a New Arsenate from Långban, *ibid. Handl. III.* 9, No. 5, 52.

11. **Aminoff, G. and Broomé, B.** Contributions to the Knowledge of the Mineral Pyroaurite, *Kungl. Svenska Vetenskapsakad. Handl. III.* 9, No. 5, 23. 12. Theoretical Structure Studies of Twins I, *Z. Krist.* 80, 355.

13. **Anderson, H. V. and Chesley, K. G.** X-ray Analysis of Slate, *Am. J. Sci.* 22, 103.

14. **Andress, K. and Reinhardt, L.** The Lattice Structure of Some Simple Sugars, *Z. Krist.* 78, 477.

15. **Andrews, A. I., Clark, G. L. and Alexander, H. W.** Progress Report on Determination of Crystalline Compounds Causing Opacity in Enamels, by X-ray Methods, *J. Am. Ceram. Soc.* 14, 634.

16. **v. Arkel, A. E. and Burgers, W. G.** X-rays Suitable for the Determination of Small Changes in the Lattice Constant of α-Iron, *Z. Metallkunde* 23, 149.

17. **Arkharov, V. I.** X-ray Study of the Initial Stage of the Process of Oxidation of Iron in Air at High Temperatures I, *J. Phys. Chem. (U.S.S.R.)* 2, 102. 18. X-ray Investigation of the Process of Oxidation of Iron at High Temperatures, *ibid.* 2, 674; *Trans. Phys.-Tech. Lab. Leningrad, Separate.*

19. **Arrhenius, S. and Westgren, A.** X-ray Analysis of Copper-Silicon Alloys, *Z. physik. Chem.* 14B, 66.

20. **Astbury, W. T.** The Molecular Structure of Natural Fibers, *Summary of Lecture Delivered at Univ. Manchester, July 10,* 1931.

21. **Astbury, W. T. and Marwick, T. C.** Structure of the Crystal Lattice of Cellulose, *Nature* 127, 12.

22. **Astbury, W. T. and Street, A.** X-ray Studies of the Structure of Hair, Wool and Related Fibers I. General, *Phil. Trans. Roy. Soc. London* 230A, 75.

23. **Astbury, W. T. and Woods, H. J.** The Molecular Weights of Proteins, *Nature* 127, 663.

24. **Bachmetew, E. F.** Rolling Texture and its Change in Relation to Degree of Working, *Metallwirtschaft* 10, 451.

25. **Bailey, E. B.** Representation of Crystal Structure, *Nature* 128, 869.

26. **Bancroft, W. D., Scherer, G. A. and Gould, L. P.** The Hypothetical Potassium Polyiodides, *J. Phys. Chem.* 35, 764.

27. **Bannister, F. A.** The Distinction of Analcite from Leucite in Rocks by X-ray Methods, *Mineralog. Mag.* 22, 469. 28. A Chemical, Optical and X-ray Study of Nephelite and Kaliophilite, *ibid.* 22, 569.

29. **Barlett, H. B.** X-ray and Microscopic Studies of Silicate Melts Containing Zirconia, *J. Am. Ceram. Soc.* 14, 837.

30. **Barnes, W. H. and Helwig, G. V.** The Space Group of Potassium Dithionate, *Can. J. Research* 4, 565.

31. **Baroni, A.** Solid Solutions between Alkali Halides, *Rendiconti accad. Lincei,* 14, 215.

Year 1931

32. **Barrett, C. S.** Laue Spots from Perfect, Imperfect and Oscillating Crystals, *Phys. Rev.* 38, 832.

33. **Barth, T. F. W. and Posnjak, E.** The Spinel Structure: An Example of Variate Atom Equipoints, *J. Wash. Acad. Sci.* 21, 255.

34. **Bearden, J. A.** Variations in the Grating Constant of Calcite Crystals, *Phys. Rev.* 38, 1389. 35. Grating Constant of Calcite Crystals, *ibid.* 38, 2089.

36. **Beckenkamp, J.** On Forces of the First and Second Kind, Nuclear Crystals and Cleavage, *Centr. Mineral. Geol.* 1931A, 65.

37. **Bennett, O. G., Cairns, R. W. and Ott, E.** Crystal Form of Nickel Oxides, *J. Am. Chem. Soc.* 53, 1179.

38. **Bennett, R. D.** X-ray Studies of Motions of Molecules in Dielectrics under Electric Stress, *J. Franklin Inst.* 211, 481.

39. **Berg, W.** An X-ray Method for Study of Lattice Disturbances of Crystals, *Naturwiss.* 19, 391.

40. **Bernal, J. D.** Results of Modern Investigation of Metals, *Ergebnisse techn. Röntgenkunde* 2, 200. 41. The Crystal Structure of the Natural Amino Acids and Related Compounds, *Z. Krist.* 78, 363.

42. **Bernal, J. D., Ewald, P. P. and Mauguin, Ch.** Abstracting Schemes for X-ray Determinations of (I) Single Substances and (II) Series of Substances, *Z. Krist.* 79, 495.

43. **Bewilogua, L.** The Accuracy of Interference Measurements in the Molecule with X- and Cathode Rays, *Physikal. Z.* 32, 114.

44. **Biltz, W., Lehrer, G. A. and Meisel, K.** Rhenium Trioxide I, II, *Nachr. Ges. Wiss. Göttingen, Math.-phys. Kl.* 1931, 191; *Z. anorg. Chem.* 207, 113 (1932).

45. **Bjurström, T.** Graphical Methods for the Estimation of the Quadratic Form of X-ray Powder Photographs, *Z. Physik* 69, 346.

46. **Bloch, R. and Möller, H.** The Modifications of Silver Iodide, *Z. physik. Chem.* 152A, 245.

47. **Boas, W. and Schmid, E.** The Dependence of Crystal Plasticity on Temperature III. Aluminum, *Z. Physik* 71, 703.

48. **Boehm, G.** Short X-ray "Interferenzaufnahmen"—A New Method for Physiologic Investigation, *Z. Biol.* 91, 203.

49. **Bowen, E. G. and Jones, W. M.** An X-ray Investigation of the Tin-Antimony Alloys, *Phil. Mag.* 12, 441.

50. **Bowen, N. L. and Posnjak, E.** Magnesian Amphibole from the Dry Melt: A Correction, *Am. J. Sci.* 22, 193.

51. **Bradley, A. J. and Gregory, C. H.** A Comparison of the Crystal Structures of Cu_5Zn_8 and Cu_5Cd_8, *Phil. Mag.* 12, 143.

52. **Bradley, A. J. and Jones, P.** The Aluminum-Manganese System of Alloys, *Phil. Mag.* 12, 1137.

53. **Braekken, H.** The Crystal Structures of the Trioxides of Chromium, Molybdenum and Tungsten, *Z. Krist.* 78, 484.

54. **Bragg, W. L.** The Architecture of the Solid State, *Nature* 128, 210, 248. 55. The Architecture of the Solid State, *J. Inst. Elec. Eng.* 69, 1239.

56. **Bragg, W. L., Gottfried, C. and West, J.** The Structure of β-Alumina, *Z. Krist.* 77, 255.

57. **Brandenberger, E.** The Crystal Structure of Koppite, *Z. Krist.* 76, 322. 58. Note on "Plaffeiit," *Schweiz. Mineralog.-Petrograph. Mitt.* 11, 181.

59. **Brantley, L. R.** The Size of the Unit Cell of Titanium Carbide, *Z. Krist.* 77, 505.

60. **Bredig, G. and v. Bergkampf, E. S.** Hexagonal Nickel, *Z. physik. Chem. Bodenstein-Festband,* 172.

61. **Brill, R.** The Determination of Size and Form of Submicroscopic Crystals with X-rays, *Kolloid-Z.* 55, 164. 62. X-ray Investigation of Iron Tetracarbonyl, *Z. Krist.* 77, 36. 63. The Lattice of Lead Chromate, *ibid.* 77, 506.

64. **Brindley, G. W.** On the Charge Distribution and Diamagnetic Susceptibility of Atoms and Ions, *Phil. Mag.* 11, 786.

65. **Broch, E. K.** Studies of the Crystal Structure of the Wolframite and Scheelite Types, *Norske Videnskaps-Akad. Skriften I,* No. 8 (1929); *Neues Jahrb. Mineral. Geol. Referate I,* 112.

66. **Broderick, S. J. and Ehret, W. F.** An X-ray Study of the Alloys of Silver with Bismuth, Antimony and Arsenic I, II, *J. Phys. Chem.* 35, 2627, 3322.

Year 1931

67. **Brownmiller, L. T. and Bogue, R. H.** Constitution of Portland Cement Studied by the X-ray Method, *Concrete (Mill Sect.)* 38, No. 2, 85; No. 3, 89.

68. **Brukl, A. and Ortner, G.** The Oxides of Gallium, *Z. anorg. Chem.* 203, 23.

69. **Brunauer, S., Jefferson, M. E., Emmett, P. H. and Hendricks, S. B.** Equilibria in the Iron-Nitrogen System, *J. Am. Chem. Soc.* 53, 1778.

70. **Buchwald, E.** Theory of X-ray Interference in p-Azoxyanisole, *Ann. Physik* 10, 558.

71. **Buerger, M. J.** The Crystal Structure of Marcasite, *Am. Mineral.* 16, 361.

72. **Büssem, W., Rosbaud, P. and Günther, P.** Crystal Structure of Rubidium Azide, *Z. physik. Chem.* 15B, 58.

73. **Bujor, D. J.** The Crystal Structure of Ammonium Chromate I, *Z. Krist.* 78, 1. 74. The Crystal Structure of Epidote I, *ibid.* 78, 386.

75. **Buschendorf, F.** A Gallium-Zinc Spinel, Ga_2ZnO_4, *Z. physik. Chem.* 14B, 297.

76. **Christiansen, V.** Hardening of Nonferrous Alloys, *Tek. Tid. Uppl. C, Bergsvetenskap* 61, 39, 47.

77. **Clark, G. L.** The Space Groups and Molecular Symmetry of Optically Active Compounds: A Reply, *J. Am. Chem. Soc.* 53, 3826. 78. X-rays in the Service of Chemistry and Industry in 1931, *J. Chem. Education* 8, 625. 79. Further X-ray Studies of Gutta-percha and Balata, *Kautschuk* 7, 177 (Reply, Hopff, E. and v. Susich, G., *ibid.* 7, 177, see 1931, 214).

80. **Clark, G. L., Ally, A. and Badger, A. E.** The Lattice Dimensions of Spinels, *Am. J. Sci.* 22, 539.

81. **Clark, G. L., Bucher, C. S. and Lorenz, O.** An extension of X-ray Researches on the Fine Structures of Colloids to Normal and Pathological Human Tissues, *Radiology* 17, 482.

82. **Clark, G. L. and Corrigan, K. E.** Industrial and Chemical Research with X-rays of High Intensity and with Soft X-rays, *Ind. Eng. Chem.* 23, 815. 83. The Long Spacings of Rubber and Cellulose, *Rubber Chem. and Techn.* 4, 213.

84. **Clark, G. L. and Pickett, L. W.** X-ray Investigations of Optically Active Compounds II. Diphenyl and Some of Its Active and Inactive Derivatives, *J. Am. Chem. Soc.* 53, 167.

85. **Clark, G. L. and Smith, H. A.** X-ray Diffraction Study of Fractionated Paraffin Waxes, *Ind. Eng. Chem.* 23, 697.

86. **Clark, J. H.** A Study of Tendons, Bones and Other Forms of Connective Tissue by Means of X-ray Diffraction Patterns, *Am. J. Physiol.* 98, 328.

87. **Colby, M. Y.** The Crystal Structure of Anhydrous Sodium Sulfate, *Z. Krist.* 77, 49. 88. The Crystal Structure of Potassium Chromate, *ibid.* 78, 168.

89. **Cork, J. M. and Gerhard, S. L.** Crystal Structure of the Series of Barium and Strontium Carbonates, *Am. Mineral.* 16, 71.

90. **Cox, E. G.** An X-ray Examination of Arabinose, Xylose and Rhamnose, *J. Chem. Soc.* 1931, 2313.

91. **Dehlinger, U.** The Reasons for the Broadening of X-ray Diffraction Lines with Powder and Rotating-crystal Photographs, *Z. Metallkunde* 23, 147. 92. Structure Changes Due to Metal Working, *Metallwirtschaft* 10, 26.

93. **Desmaroux and Mathieu.** The Structure of Nitrocelluloses, *Compt. rend.* 192, 234.

94. **Dittler, E. and Lasch, H.** New Synthetic Investigations in the Feldspar Group, *Sitzungsber. Akad. Wiss. Wien, Math.-naturw. Kl. Abt. I.* 140, 633.

95. **Donath, M.** Zinc-bearing Chromite, *Am. Mineral.* 16, 484.

96. **Drier, R. W.** X-ray Study of the Copper End of the Copper-Silver System, *Ind. Eng. Chem.* 23, 404, 970. 97. Appearance of Extra Lines in X-ray Diffraction Patterns of Mixtures and Absence of Some Lines Peculiar to the Components of the Mixtures, *Phys. Rev.* 37, 712.

98. **Dupré la Tour, F.** The Polymorphism of Malonic, Succinic and Glutaric Acids as a Function of the Temperature, *Compt. rend.* 193, 180.

99. **Dziengel, K., Trogus, C. and Hess, K.** Acetolysis of Cellulose IV. Relation between Cellulose and Cellulose Dextrins. Preparation of Crystalline Cellulose Acetate II, *Ann. Chem. (Liebig's)* 491, 52.

100. **Ebert, F.** The Crystal Structure of Some Fluorides of the Eighth Group of the Periodic System, *Z. anorg. Chem.* 196, 395. 101. Graphical or Mechanical Solution of Powder Photographs of Cubic, Hexagonal, Tetragonal or Orthorhombic Symmetry, *Z. Krist.* 78, 489.

Year 1931

102. **Edwards, D. A.** A Determination of the Complete Crystal Structure of Potassium Nitrate, *Z. Krist.* 80, 154.

103. **Ehrenberg, H.** Synthesis of β-Calcium Orthosilicate (Wollastonite) by a Reaction between Solids, *Z. physik. Chem.* 14B, 421.

104. **Eissner, W. and Brill, R.** Crystallographic and X-ray Investigation of Hexabromobutylene (Diacetylene Hexabromide), *Z. Krist.* 79, 430.

105. **Ekman, W.** Structural Analogies of Binary Alloys of Transition Elements and Zinc, Cadmium and Aluminum, *Z. physik. Chem.* 12B, 57.

106. **Eulitz, W.** The Structure of Silicic Acid Methyl Ester, *Z. Krist.* 80, 204.

107. **Ewald, P. P.** Remarks on the Conception of "Stase," "Textur" and "Phase," *Z. Krist.* 79, 299. 107a. Strukturbericht, *Z. Krist. Ergänzungsband* 1931.

108. **Ferrari, A.** Isomorphism Considered in its Relation to X-ray Investigations, *Gazz, chim. ital.* 61, 358. 109. Structure of Matter in the Solid State, *Scientia* 48, 371.

110. **Ferrari, A. and Colla, C.** The Importance of Crystalline Form in the Formation of Solid Solutions VIII. Thermal and X-ray Analysis of the System Li_2Br_2-$MgBr_2$ Anhydrous, *Rendiconti accad. Lincei* 13, 78. 111. Chemical and Crystallographic Determinations on Complex Nitrites, *ibid.* 14, 435. 111a. II. Double Nitrites of Potassium and Nickel and Potassium and Cobalt, *ibid.* 14, 511.

112. **Ferrari, A. and Scherillo, A.** The Crystal Structure of Manganite, *Z. Krist.* 78, 496. 113. Crystallographic Studies of Some Organic Substances, *ibid.* 80, 45.

114. **Fink, W. L., Van Horn, K. R. and Budge, P. M.** Constitution of High-Purity Aluminum-Titanium Alloys, *Am. Inst. Min. Met. Eng., Tech. Pub.* No. 393.

115. **Fink, W. L., Van Horn, K. R. and Pazour, H. A.** Thermal Decomposition of Alunite, *Ind. Eng. Chem.* 23, 1248.

116. **Forestier, H.** Ferrites: Relation between their Crystal Structure and their Magnetic Properties, *Compt. rend.* 192, 842.

117. **Forestier, H. and Galand, M.** Beryllium Ferrite and Ferric Oxide from its Decomposition, *Compt. rend.* 193, 733.

118. **Fox, G. W. and Carr, P. H.** The Effect of Piezoelectric Oscillation on the Intensity of X-ray Reflections from Quartz, *Phys. Rev.* 37, 1622.

119. **Fox, G. W. and Cork, J. M.** The Regular Reflection of X-rays from Quartz Crystals Oscillating Piezoelectrically, *Phys. Rev.* 38, 1420.

120. **Fujiwara, T.** The Effect of Heat Treatment on the Crystal Arrangement of Tungsten and Molybdenum Wire, *Proc. World Eng. Cong. Tokyo 1929*, 36, 171. 121. Arrangement of Microcrystals in Rolled Foils of Tungsten and Molybdenum, *ibid.* 36, 179.

122. **Fukusima, E.** Determination of the Parameter of Calcite by the Temperature Effect, *J. Sci. Hiroshima Univ.* 1A, 195.

123. **Gajewski, H.** X-ray Interference by Di- and Triatomic Molecules of Light Gases, *Physikal. Z.* 32, 219.

124. **Garrido, J.** Structural Relations between Argentite and Acanthite, *Anales soc. españ. fís. quím.* 29, 505 (Reply, Palacios, J. and Salvia, R., *ibid.* 29, 514, see 1931, 345).

125. **Gensamer, M., Eckel, J. F. and Walters, F. M., Jr.** Alloys of Iron, Manganese and Carbon III. X-ray Study of the Binary Iron-Manganese Alloys, *Mining Met. Investigations Bull.* 101, 23; *Trans. Am. Soc. Steel Treating* 19, 599 (1932).

126. **Glocker, R. and Schäfer, K.** Determination of Atomic Scattering Powers in the Region of Anomalous Dispersion, *Z. Physik* 73, 289.

127. **Goetz, A. and Hergenrother, R. C.** Macroscopic and Lattice Expansion of Bi Single Crystals, *Phys. Rev.* 38, 2075.

128. **Goldschmidt, V. M.** The Crystal Chemistry of Germanium, *Nachr. Ges. Wiss. Göttingen, Math.-phys. Kl.* 1931, 184. 129. The Crystal Chemical Relations between Gallium and Aluminum, Germanium and Silicon, *Norsk geol. tidss.* 12, 247. 130. Crystal Chemistry, *Fortschr. Min. Krist. Pet.* 15, 973. 131. Crystal Chemistry and X-ray Research, *Ergebnisse techn. Röntgenkunde* 2, 151.

132. **Goldsztaub, S.** Dehydration of Natural Ferric Hydrates, *Compt. rend.* 193, 533.

133. **Goss, N. P.** Practical Application of X-ray Diffraction Methods in the Study of Quench and Temper Structures of Carbon Spring Steels, *Trans. Am. Soc. Steel Treating* 19, 182.

134. **Gossner, B. and Koch, I.** The Crystal Lattice of Langbeinite, Northupite and Hanksite, *Z. Krist.* 80, 455.

Year 1931

135. **Gossner, B. and Mussgnug, F.** The Molecular Unit of Pyrosmalite, *Z. Krist.* **76,** 525. **135a.** X-ray Study of Prehnite and Lawsonite, *Centr. Mineral. Geol.* **1931A,** 419.

136. **Gottfried, C.** New Results of X-ray Investigation among Inorganic Compounds, *Ergebnisse techn. Röntgenkunde* **2,** 183.

137. **Graf, L.** Contributions to the Knowledge of the Preparation of Metal Crystals, *Z. Physik* **67,** 388.

138. **Greenwood, G.** A Further Study of Triphenylbismuthine Dichloride Crystals, *Am. Mineral.* **16,** 473.

139. **Greenwood, G. and Parsons, A. L.** The Lattice Dimensions of Certain Monoclinic Amphiboles, *Univ. Toronto Studies, Geol. Ser.* **No. 30,** 29.

140. **Grime, G.** An X-ray Apparatus for Powder Analysis, *J. Sci. Instruments* **8,** 197.

141. **Gross, B.** Calculation of the Coulomb Lattice Energy for Crystals of the Wurtzite Type, *Z. Krist.* **76,** 562.

142. **Gruner, J. W.** Structures of Some Silicates, *Am. Mineral.* **16,** 437.

143. **Hägg, G.** Transition Element Compounds with Low Atomic Weight Metalloids, *Svensk Kem. Tids.* **43,** 187. **144.** X-ray Investigations on the Hydrides of Titanium, Zirconium, Vanadium and Tantalum, *Z. physik. Chem.* **11B,** 433. **145.** Regularity in Crystal Structure in Hydrides, Borides, Carbides and Nitrides of Transition Elements, *ibid.* **12B,** 33. **146.** Correction of the Article "Crystal Structure of the Compound Fe_2B," *ibid.* **12B,** 413. **147.** Metallic Nitrides, Carbides, Borides and Hydrides, *Metallwirtschaft* **10,** 387.

148. **Hahn, T. M.** An X-ray Powder Diffraction Apparatus of New Design, *Rev. Sci. Instruments* **2,** 626.

149. **Halla, F.** Isomorphous Relations and Double Salt Formation between Gypsum and Brushite, *Z. Krist.* **80,** 349.

150. **Halla, F. and Mehl, E.** The Space Lattice of Cobaltous Ammonium Sulfate Hexahydrate, *Z. anorg. Chem.* **199,** 379.

151. **Halla, F. and Tandler, R.** Note on Collagen Fiber, *Z. physik. Chem.* **12B,** 89.

152. **Halla, F., Bosch, F. X. and Mehl, E.** X-ray Studies in the Sulfur-Selenium System II. The Space Lattice of Monoclinic Selenium (First Modification), *Z. physik. Chem.* **11B,** 455.

153. **Halla, F., Mehl, E. and Bosch, F. X.** X-ray Studies in the Sulfur-Selenium System III. The Space Lattice of Mixed Crystals of the γ-Sulfur Type (Type A according to Groth), *Z. physik. Chem.* **12B,** 377.

154. **Halle, F.** X-ray Measurements on Homologous Normal Polymethylene Compounds in Oriented Crystalline Layers, *Kolloid-Z.* **56,** 77.

155. **Hallimond, A. F.** Geochemistry, *Ann. Repts. Chem. Soc. for 1930,* **27,** 283.

156. **Hanemann, H., Herrmann, K., Hofmann, U. and Schrader, A.** The Processes in the Formation of the Martensite Structure, *Arch. Eisenhüttenw.* **4,** 479.

157. **Harder, O. E. and Todd, G. B.** Correlation of the Crystal Structures and Hardnesses of Nitrided Cases, *Trans. Am. Soc. Steel Treating* **19,** 41.

158. **Hartwig, W.** The Structure of Analcite, *Z. Krist.* **78,** 173.

159. **Harvey, G. G.** Diffuse Scattering of X-rays from Sylvine, *Phys. Rev.* **38,** 593.

160. **Hassel, O.** The Symmetry of Molecules and Ions of the Composition AX_m, *Tids. Kemi Bergvaesen* **11,** 92. **161.** The Cyclohexane Problem, *Z. Elektrochem.* **37,** 540. **162.** Structure of Hexammino and Hexaquo Salts, *Z. Krist.* **79,** 531.

163. **Hassel, O. and Kringstad, H.** The Crystal Structure of the Tetrahalogenides of Light Elements. Determination of the Structure of Silicon Tetraiodide, *Z. physik. Chem.* **13B,** 1. **164.** Crystalline Carbon Tetraiodide, *Tek. Ukeblad* **78,** 230.

165. **Hauser, E. A. and von Susich, G.** Study by Means of X-rays of the Structure of Gutta-percha I, II, III, *Kautschuk* **7,** 120, 125, 145; *Rev. gén. caoutchouc* **8,** No. 72, 3. **166.** Graphical Examination with X-rays of the Structure of Gutta-percha, *ibid.* **8,** Nos. 75, 76.

167. **Hedvall, J. A. and Sjöman, P.** The Importance of Crystallographic Changes in Silica in its Reactivity in the Solid State I, *Z. Elektrochem.* **37,** 130.

168. **Heisenberg, W.** Incoherent Scattering of X-radiation, *Physikal. Z.* **32,** 737.

169. **Hemon, Y.** Crystallographic Study of Cesium Bitartrate, *Bull. soc. franç. min.* **54,** 47.

170. **Hendricks, S. B.** The Crystal Structure of N_2O_4, *Z. Physik* **70,** 699.

Year 1931

171. **Hendricks, S. B. and Hilbert, G. E.** The Molecular Association, the Apparent Symmetry of the Benzene Ring, and the Structure of the Nitro Group in Crystalline m-Dinitrobenzene. The Valences of Nitrogen in Some Organic Compounds, *J. Am. Chem. Soc.* 53, 4280.

172. **Hendricks, S. B., Hill, W. L., Jacob, K. D. and Jefferson, M. E.** Structural Characteristcs of Apatite-like Substances and Composition of Phosphate Rock and Bone as Determined from Microscopical and X-ray Diffraction Examinations, *Ind. Eng. Chem.* 23, 1413.

173. **Hengstenberg, J. and Lenel, F. V.** The Structure of Glycine, *Z. Krist.* 77, 424.

174. **Hengstenberg, J. and Mark, H.** X-ray Investigation of Lattice Disturbances in Light Metals, *Z. Elektrochem.* 37, 524.

175. **Hengstenberg, J. and Wassermann, G.** X-ray Studies upon the Age-hardening of Duralumin at Ordinary Temperatures, *Z. Metallkunde* 23, 114.

176. **Herlinger, E.** The Effective Radii (Domains) of Atoms and Ions in Crystals I, *Z. Krist.* 80, 465.

177. **Hermann, C.** Remarks on the Preceding Work of Ch. Mauguin, *Z. Krist.* 76, 559. 178. The Symmetry Groups of Amorphous and Mesomorphous Phases, *ibid.* 79, 186.

179. **Herrmann, K. and Ilge, W.** The Structure of Silver Sulfate, *Z. Krist.* 80, 402.

180. **Herrmann, K. and Krummacher, A. H.** X-ray Examination of Liquid Crystalline Substances II. Allyl Phenetylazoxybenzoate, *Z. Krist.* 79, 134. 181. III. Anisal-1.5-Diaminonaphthalene, *Z. Physik* 70, 758.

182. **Herrmann, K., Krummacher, A. H. and May, K.** The Behavior of Liquid Crystalline Substances in an Electric Field (X-ray and Optical Investigation), *Z. Physik* 73, 419.

183. **Herrmann, Z.** The Structure of Strontium Bromide Hexahydrate, *Z. anorg. Chem.* 196, 79. 184. The Structure of the Hexahydrates of Strontium Iodide, Calcium Chloride and Calcium Bromide, *ibid.* 197, 212. 185. The Structure of Barium Iodide and Calcium Iodide Hexahydrates. Complete Structure of the Alkaline Earth Halide Hydrates of the Type $SrCl_2 \cdot 6H_2O$, *ibid.* 197, 339.

186. **Hertel, E.** Structure of Compounds of Sulfur with Iodides I. Compounds of Sulfur with Triiodides, *Z. physik. Chem.* 15B, 51. 187. The Structure of the Molecular Compound in Veramon, *ibid. Bodenstein-Festband,* 267.

188. **Hertel, E. and Römer, G. H.** The Crystal Structure of p-Nitrostilbene, *Z. Krist.* 76, 467.

189. **Hertel, E. and Schneider, K.** Comparison of the Crystal Structures of an Addition and a Substitution Compound, *Z. physik. Chem.* 12B, 109. 190. Polymerization in Crystal Lattice—Crystal Structure of Trinitroresorcinol and Trinitrophloroglucinol, *ibid.* 12B, 139. 191. Complex Isometry. The Theory of Crystallization of Complex Isomer Modifications. The Crystal Structure of a Few Complex Isomer Modifications, *ibid.* 13B, 387. 192. Crystal Structure of an Organic Molecular Compound of the Type AB_2, *ibid.* 15B, 79. 193. Investigations of "Magnus' Salts," *Z. anorg. Chem.* 202, 77. 194. Transformations in Crystal Lattices, *Z. Elektrochem.* 37, 536.

195. **Herzog, G.** Scattering of X-rays in Argon, *Z. Physik* 69, 207. 196. Scattering of X-rays in Neon and Argon, *ibid.* 70, 583. 197. The Scattering of X-rays by Helium, *ibid.* 70, 590.

198. **Herzog, R. O. and Jancke, W.** Note on the X-ray Diagram of Collagen (Fiber Period), *Z. physik. Chem.* 12B, 228.

199. **Herzog, R. O., Kratky, O. and Kuriyama, S.** An Apparent Crystallographic Anomaly of Choleic Acid, *Naturwiss.* 19, 524.

200. **Hess, F. L. and Henderson, E. P.** Fervanite, a Hydrous Ferric Vanadate, *Am. Mineral.* 16, 273.

201. **Hess, K. and Trogus, C.** X-ray Studies of Cellulose Derivatives VIII. The Alkali Celluloses, *Z. physik. Chem.* 11B, 381. 202. X. The Fiber Periods of Cellulose Derivatives, *ibid. Bodenstein-Festband,* 385.

203. **Hess, K., Trogus, C., Akim, L. and Sakurada, I.** Morphology and Chemism in Cellulose Fibers, *Ber.* 64B, 408.

204. **Hey, J. S. and Taylor, W. H.** The Coordination Number of Aluminum in the Aluminosilicates, *Z. Krist.* 80, 428.

Year 1931

205. **Heyworth, D.** Crystal Structure of Arsenic Triiodide, *Phys. Rev.* 38, 351. 206. Note on the Crystal Structure of Arsenic Triiodide, *ibid.* 38, 1792.

207. **Hibbert, H. and Barsha, J.** Structure of the Cellulose Synthesized by the Action of *Acetobacter xylinus* on Glucose, *Can. J. Research* 5, 580.

208. **Hirata, M.** X-ray Diffraction by Incandescent Carbon, *Sci. Pap. Inst. Phys. Chem. Research (Tokyo)* 15, 219.

209. **Hocart, R. and Serres, A.** Magnetic Properties and Crystalline Structure in the Different Varieties of Anhydrous Cobalt Sulfate, *Compt. rend.* 193, 1180.

210. **Hofmann, U.** Adsorptive Capacity, Catalytic Activity and Crystalline Structure of Carbon, *Z. angew. Chem.* 44, 841.

211. **Hofmann, W.** The Structure of Tutton's Salts, *Z. Krist.* 78, 279.

212. **Holgersson, S. and Herrlin, A.** X-ray Investigation of the Orthotitanates, *Z. anorg. Chem.* 198, 69.

213. **Hollabaugh, C. B. and Davey, W. P.** Preferred Orientation Produced by Cold Rolling in the Surface of Sheets of Aluminum, Nickel, Copper and Silver, *Am. Inst. Min. Met. Eng., Inst. Metals Div., Boston Meeting, Sept.* 1931; *Metals and Alloys* 2, 246, 302.

214. **Hopff, E. and v. Susich, G.** A Study of Gutta-percha and Balata by Means of X-ray Spectra, *Rubber Chem. and Techn.* 4, 75; *Kautschuk* 7, 177.

215. **Huggins, M. L.** Arrangement of Atoms in Crystals, *Phys. Rev.* 37, 447. 216. The Application of X-rays to Chemical Problems, *J. Phys. Chem.* 35, 1216. 217. Principles Determining the Arrangement of Atoms and Ions in Crystals, *ibid.* 35, 1270. 218. Solid Matter—What is it, and Why? *Sci. Monthly* 1931, 140. 219. The Use of the Theory of Space Groups in Crystal Structure Determinations, *J. Am. Chem. Soc.* 53, 3823.

220. **Huggins, M. L. and Frank, G. O.** The Crystal Structure of Potassium Dithionate, *Am. Mineral.* 16, 580.

221. **Huggins, M. L. and Noble, B. A.** The Crystal Structure of Iodoform, *Am. Mineral.* 16, 519.

222. **Hüttig, G. F. and Steiner, B.** Oxide Hydrates and Active Oxides XL. The System Lead (II) Oxide-Water, *Z. anorg. Chem.* 197, 257.

223. **Iliin, B. and Simanov, I.** The Nature of Specific Properties of Molecular Surface Fields. The Structure of Active Carbons and the Inversion of the Effects of Adsorption and Wetting Heats II, *Z. Physik* 70, 559.

224. **Iwasê, K., Aoki, N. and Ôsawa, A.** The Equilibrium Diagram of the Tin-Antimony System and the Crystal Structure of the β-Solid Solution, *Sci. Repts. Tôhoku Imp. Univ.* 20, 353; *Kinzoku-no-Kenkyu* (*J. Study of Metals*) 7, 147; *J. Inst. Metals* 43, 452.

225. **Jaeger, F. M. and Rosenbohm, E.** The Exact Measurement of the Specific Heat of Osmium and Rhodium between 0° and 1625° C, *Proc. Acad. Sci. Amsterdam* 34, 85.

226. **Jaeger, F. M. and Zanstra, J. E.** The Allotropism of Rhodium and Some Phenomena Observed in the X-ray Analysis of Heated Metal Wires, *Proc. Acad. Sci. Amsterdam* 34, 15.

227. **Jakob, J. and Brandenberger, E.** Chemical and X-ray Investigations on the Amphiboles I, *Schweiz. Mineralog.-Petrograph. Mitt.* 11, 140.

228. **Jakob, J., Parker, R. L. and Brandenberger, E.** A New Source of Scapolite in Tessin, *Schweiz. Mineralog.-Petrograph. Mitt.* 11, 267.

230. **James, R. W. and Brindley, G. W.** Some Numerical Values of the Atomic Scattering Factor, *Z. Krist.* 78, 470. 231. Some Numerical Calculations of Atomic Scattering Factors, *Phil. Mag.* 12, 81.

232. **Jauncey, G. E. M.** Theory of the Diffuse Scattering of X-rays by Solids, *Phys. Rev.* 37, 1193. 233. Scattering of X-rays by Gases and Crystals, *ibid.* 38, 1. 234. The Scattering of X-rays from Polyatomic Gases, *ibid.* 38, 194.

235. **Jauncey, G. E. M. and Harvey, G. G.** Theory of the Diffuse Scattering of X-rays by Simple Cubic Crystals, *Phys. Rev.* 37, 1203. 236. A Relation between the Scattering of X-rays by Gases and Crystals, *ibid.* 38, 1071. 237. Diffuse Scattering of X-rays from Sylvine at Low Temperature, *ibid.* 38, 1925.

238. **Jenkins, C. H. M. and Preston, G. D.** Some Properties of Metallic Cadmium, *J. Inst. Metals* 45, 307.

239. **Jesse, W. P.** X-ray Measurements of the Elastic Deformation of Metals, *Phys. Rev.* 37, 1017.

Year 1931

240. **Jung, H.** "Molybdenum-bearing Stolzite" from Zinnwald, *Neues Jahrb. Mineral. Geol. Beilage-Bd.* **64A**, 197.

241. **Kabraji, K. J.** Crystal Structure of the Hydrates of Copper Formate I. Copper Formate Tetrahydrate. II. Copper Formate Dihydrate, *Indian J. Physics* **6**, 81, 115.

242. **Kästner, F.** The Crystal Structure of Analcite I, *Z. Krist.* **77**, 353.

243. **Kästner, F. and Mayer, F. K.** Minerals of the Clay Group I, *Chem. Erde* **6**, 269.

244. **Katoh, N.** X-ray Investigation of the Gold-Aluminum System I, II, *J. Chem. Soc. Japan* **52**, 851, 854.

245. **Katz, J. R. and Derksen, J. C.** An Explanation of the Swelling Effect of Thiocyanates on Cellulose; Compounds of Cellulose with Neutral Salts, *Rec. trav. chim.* **50**, 149. 246. The Change in X-ray Spectrum of Inulin on Swelling in Water, *ibid.* **50**, 248. 247. Description of the Changes of the X-ray Spectrum with the Swelling of Cellulose in Aqueous Lithium Thiocyanate Solutions, *ibid.* **50**, 736. 248. Lattice Variations with Swelling of Acetylcellulose in Aqueous Lithium Thiocyanate Solutions, *ibid.* **50**, 746.

249. **Katz, J. R. and v. Itallie, Th. B.** The Physical Chemistry of Starch and Bread Making VII. The X-ray Spectra of the Two Constituents of Starch: Amylopectin and Amylose, *Z. physik. Chem.* **155A**, 199.

250. **Katz, J. R. and Weidinger, A.** Polymorphism of Substances of High Molecular Weight II. Amorphous and Crystalline Inulin, *Rec. trav. chim.* **50**, 1133.

251. **Katz, J. R., Derksen, J. C. and Bon, W. F.** Difference between the X-ray Spectra of Gelatin Sol and Gelatin Gel, *Rec. trav. chim.* **50**, 1138.

252. **Kelley, W. P., Dore, W. H. and Brown, S. M.** The Nature of the Base-exchange Material of Bentonite, Soils and Zeolites as Revealed by Chemical Investigation and X-ray Analysis, *Soil Science* **31**, 25.

253. **Kenney, A. W. and Aughey, H.** X-ray Diffraction Patterns of Mixtures, *Phys. Rev.* **38**, 1388.

254. **Kerr, P. F.** Bentonite from Ventura, California, *Econ. Geol.* **26**, 153.

255. **Kersten, H.** The Crystal Structure of Copper Electrodeposited in the Presence of Gelatin, *J. Phys. Chem.* **35**, 3644.

256. **Ketelaar, J. A. A.** Structure of the Trifluorides of Aluminum, Iron, Cobalt, Rhodium and Palladium, *Nature* **128**, 303. 257. Structure Determination of the Complex Mercury Compounds Ag_2HgI_4 and Cu_2HgI_4, *Z. Krist.* **80**, 190.

258. **Kiessig, H.** Interference of X-rays on Thin Layers, *Ann. Physik* **10**, 769.

259. **Klages, F.** Cellulose XLII. Formation from Cellulose Fibers of a Crystalline Carbohydrate Soluble in Water and Giving the X-ray Diagram of Hydrocellulose, *Ber.* **64B**, 1193.

260. **Klanfer, K. and Pavelka, F.** Aging Phenomena in Chromium Hydroxide Gels, *Kolloid-Z.* **57**, 324.

261. **Knaggs, I. E.** The Molecular Symmetry of Hexa-Aminobenzene in the Crystalline State and Certain Other Properties of the Substance, *Proc. Roy. Soc. (London)* **131A**, 612.

262. **Körber, E. and Schiebold, E.** "Fortschritte der Röntgenforschung in Methode und Anwendung," Leipzig (1931).

263. **Kolkmeijer, N. H. and Moesveld, A. L. Th.** Precision Measurements of the Dimensions of Crystal Lattices, *Z. Krist.* **80**, 63. 264. The Density and Structure of Millerite, Rhombohedral NiS, *ibid.* **80**, 91.

265. **Kracek, F. C., Hendricks, S. B. and Posnjak, E.** Group Rotation in Solid Ammonium and Calcium Nitrates, *Nature* **128**, 410.

266. **Kracek, F. C., Posnjak, E. and Hendricks, S. B.** Gradual Transition in Sodium Nitrate II. The Structure at Various Temperatures and its Bearing on Molecular Rotation, *J. Am. Chem. Soc.* **53**, 3339.

267. **Kratky, O.** Two New Methods of Interpreting Photographs Made with Convergent X-rays, *Z. Krist.* **76**, 517.

268. **Kratky, O. and Kuriyama, S.** Silk Fibers III, *Z. physik. Chem.* **11B**, 363.

269. **Krause, O. and Thiel, W.** The Structure of Some Ceramic Coloring Materials Containing Aluminum Oxide, *Z. anorg. Chem.* **203**, 120.

270. **Krause, O. and Ksinsik, W.** X-ray Study of Magnesite Bricks, *Feuerfest Ofenbau* **7**, 177.

271. **Krejči, L. and Ott, E.** The Structure of Silica Gel (X-ray Study), *J. Phys. Chem.* **35**, 2061.

Year 1931

272. **Ksanda, C. J.** Comparison Standards for the Powder Spectrum Method: NiO and CdO, *Am. J. Sci.* 22, 131. 273. A Pantograph for Enlarging X-ray Photographs, *Rev. Sci. Instruments* 2, 305.

274. **Lânyi, B. and Szarvasy, I.** The Graphitization of Diamond, *Math. naturw. Anz. ungar. Akad. Wiss.* 48, 137.

275. **Lashkarev, V. and Alichanian, A.** Asterism in Laue Photographs of Rock Salt and Internal Tensions, *Z. Krist.* 80, 353.

276. **v. Laue, M.** The Dynamic Theory of X-ray Interference in a New Form, *Ergebnisse exakt. Naturwiss.* 10, 133. 277. Remark on the History of the Dynamic Theory of X-ray Interference, *Naturwiss.* 19, 966.

278. **Laves, F.** Plane Sharing and Coordination Number, *Z. Krist.* 78, 208.

279. **Lenel, F. V.** Study of E. Fischer's Polypeptides with X-rays, *Naturwiss.* 19, 19.

280. **Leonhardt, J.** X-ray Anomalies of Crystals, *Neues Jahrb. Mineral. Geol. Beilage-Bd.* 64A, 1.

281. **Lester, H. H.** X-rays in the Steel Industry, *J. Franklin Inst.* 211, 567.

282. **Levi, G. R. and Scherillo, A.** Crystallographic Investigation of the Salts of Chlorous Acid, *Z. Krist.* 76, 431.

283. **Lonsdale, K.** An X-ray Analysis of the Structure of Hexachlorobenzene, Using the Fourier Method, *Proc. Roy. Soc.* (*London*) 133A, 536.

284. **McCrea, G. W.** An X-ray Study of Mannitol, *Nature* 127, 162.

285. **McKeehan, L. W.** Elements of X-ray Analysis by the Powder Method, *Metal Progress* 19, 71.

286. **Machatschki, F.** The Structure of Spinel, *Z. Krist.* 80, 416.

287. **Malkin, T.** Alteration in Long-chain Compounds. New X-ray Data for Long-chain Ethyl and Methyl Esters and Iodides and a Preliminary Thermal Examination of the Esters, *J. Chem. Soc.* 1931, 2796.

288. **Mark, H.** Recent Advances in the Interferometric Determination of the Form of Molecules I, *Z. angew. Chem.* 44, 125. 289. II. *ibid.* 44, 525.

290. **Martin, E. J., Faulkner, D. W. and Fessler, A. H.** X-ray Diffraction Examination of High-fired Porcelain, *J. Am. Ceram. Soc.* 14, 844.

291. **Marwick, T. C.** An X-ray Study of Mannitol, Dulcitol and Mannose, *Proc. Roy. Soc.* (*London*) 131A, 621. 292. The X-ray Classification of Epidermal Proteins, *J. Textile Sci.* 4, 31. 293. An X-ray Study of Mannitol, Dulcitol and Mannose, *Nature* 127, 11.

294. **Masing, G.** Refining of Alloys, Especially on the Basis of Investigations of Light Metals and of Beryllium Alloys, *Z. Elektrochem.* 37, 414.

295. **Matuyama, Y.** On the Question of the Allotropy of White Tin and the Equilibrium Diagram of the System Tin-Cadmium, *Sci. Repts. Tôhoku Imp. Univ.* 20, 649.

296. **Mauguin, Ch.** The Symbolism of Groups of Repetition or the Symmetry of Crystalline Assemblages, *Z. Krist.* 76, 542.

297. **Mayer, F. K.** Results of Particle Size Determination by Means of X-rays, *Kolloid-Z.* 57, 353.

298. **Mehmel, M.** Relations between Crystal Structure and Chemical Formula of Apatite, *Z. physik. Chem.* 15B, 223.

299. **Menzer, G.** The Crystal Structure of Eulytite, *Z. Krist.* 76, 454; 78, 136.

300. **Meyer, A. W.** The Diffraction of X-rays in Organic Mixtures, *Phys. Rev.* 38, 1083.

301. **Meyer, K. H. and Mark, H.** Remarks on the Papers of H. Staudinger: Structure of Highly Polymerized Compounds, *Ber.* 64B, 1999.

302. **Miles, F. D.** The Apparent Hemihedrism of Crystals of Lead Chloride and Some Other Salts, *Proc. Roy. Soc.* (*London*) 132A, 266.

303. **Millosevich, F.** Larderellite and Paternoite, *Per. mineral.* 1, 214; *Neues Jahrb. Mineral. Geol. Referate I,* 229 (1932).

304. **Möller, H.** The Crystal Structure of $B_{10}H_{14}$, *Z. Krist.* 76, 500.

305. **Moeller, K.** The Lattice Constants of Rhenium, *Naturwiss.* 19, 575.

306. **Mooney, R. C. L.** The Crystal Structure of Potassium Permanganate, *Phys. Rev.* 37, 1306.

307. **Mooy, H. H.** Crystal Structure of Methane, *Nature* 127, 707. 308. On the Crystal Structure of Methane, *Proc. Acad. Sci. Amsterdam* 34, 550. 309. II, *ibid.* 34, 660.

Year 1931

310. **Morton, G. A.** Atomic Scattering Power of Copper and Oxygen in Cuprous Oxide, *Phys. Rev.* 38, 41.

311. **Müller, A.** Further Estimates of the Input Limits of X-ray Generators, *Proc. Roy. Soc. (London)* 132A, 646.

312. **Mukhin, G. E. and Chalenko, I. I.** Diffraction of X-rays by Organic Liquids, *Ukrainskii Khem. Zhur.* 6, No. 1, *Sci. Pt.* 9.

313. **Murphy, A. J.** Constitution of the Alloys of Silver and Mercury, *J. Inst. Metals* 46, 507.

314. **Nagelschmidt, G.** The Structure and the Symmetry Relationships of the Complex Cyanides of the Type of Potassium Ferricyanide, *Veröffentlich. Kaiser Wilhelm-Inst. Silikatforsch. Berlin-Dahlem* 4, 27.

315. **Natta, G.** Structure of Hydrogen Sulfide and Hydrogen Selenide, *Nature* 127, 129. 316. The Crystal Structure and Polymorphism of Hydrogen Halides, *ibid.* 127, 235. 317. The Dimensions of Atoms and Univalent Ions in the Lattices of Crystals, *Mem. accad. Italia, Cl. sci. fis. mat. nat.* 2, *Chim.* No. 3, 5.

318. **Natta, G. and Passerini, L.** Thio Salts Having the Spinel Structure, *Rendiconti accad. Lincei* 14, 38. 319. The Structure of Alkali Cyanides and their Isomorphism with Halides, *Gazz. chim. ital.* 61, 191.

320. **Neskuchaev, V.** A Simple Method for the Determination of Debye-Scherrer X-ray Structure of Non-cubic Systems, *J. Tech. Phys. (U.S.S.R.)* 1, 105.

321. **Neuburger, M. C.** Precisions Measurements of the Lattice Constant of Cuprous Oxide, *Z. Physik* 67, 845. 322. The Lattice Constant of Cuprous Oxide, *Z. Krist.* 77, 169. 323. Precision Measurements of the Lattice Constant of Columbium, *Z. anorg. Chem.* 197, 219. 324. The Density, Crystal Structure and Lattice Constant of Columbium, *Z. Krist.* 78, 164. 325. Lattice Constants 1931, *ibid.* 80, 103.

326. **Nial, O., Almin, A. and Westgren, A.** X-ray Analysis of the Systems: Gold-Antimony and Silver-Tin, *Z. physik. Chem.* 14B, 81.

327. **Niggli, P.** Stereochemistry of Crystalline Compounds V. Dependence of Structure Types of Crystalline Compounds of the Type AB and BAB on Lattice Energy, *Z. Krist.* 77, 140. 328. The Structure of Metals in Comparison with Other Crystal Structures, *Schweiz. Mineralog.-Petrograph. Mitt.* 11, 290.

329. **Niggli, P. and Brandenberger, E.** Stereochemistry of Crystalline Compounds VI. Compounds of Type AB_2. Geometrical Derivation of the Types to be Expected, *Z. Krist.* 79, 379.

330. **Nishikawa, S., Sakisaka, Y. and Sumoto, I.** Note on "the Effect of Piezoelectric Oscillation on the Intensity of X-ray Reflections from Quartz," *Phys. Rev.* 38, 1078.

331. **Nishiyama, Z.** The Electric Resistance of Carbon, *Z. Physik* 71, 600; *Sci. Repts. Tôhoku Imp. Univ.* 21, 171 (1932).

332. **Nusbaum, C.** X-ray Analysis of Cold Rolling and Recrystallization in Steel, *Phys. Rev.* 37, 458.

333. **Nussbaum, R., Jr. and Frolich, P. K.** Catalysts for Formation of Alcohol from Carbon Monoxide and Hydrogen VII. Studies of Reduction of Methanol Catalyst, *Ind. Eng. Chem.* 23, 1386.

334. **Obinata, I.** Nature of Eutectoid Transformation of Aluminum Bronze III. X-ray Analysis. IV. X-ray Analysis at High Temperature, *Mem. Ryojun Coll. Eng.* 3, No. 4B, 285, 295.

335. **Oftedal, I.** The Crystal Structure of Tysonite $(Ce,La,\ldots)F_3$, *Z. physik. Chem.* 13B, 190. 336. The Crystal Structure of Bastnäsite $(Ce,La,\ldots)FCO_3$, *Z. Krist.* 78, 462. 337. Parisite, Synchisite and Cordylite. X-ray Investigations, *ibid.* 79, 437. 338. Parallel Growth of Tysonite and Bastnäsite, *Norsk. Geol. Tidss.* 12, 459.

339. **Öhman, E.** Crystal Structure of Martensite, *Nature* 127, 270. 340. The Structure, Formation and Decomposition of Martensite, *Jernkontorets Ann.* 115, 325. 341. X-ray Investigations on the Crystal Structure of Hardened Steel, *J. Iron Steel Inst.* 123, 445.

342. **Ôsawa, A.** X-ray Investigation of Iron and Manganese Alloys, *Proc. World Eng. Cong. Tokyo 1929,* 34, 293.

343. **Ôsawa, A. and Takeda, S.** An X-ray Investigation of Alloys of the Iron-Tungsten System and their Carbides, *Kinzoku-no-Kenkyu* 8, 181; *J. Inst. Metals* 47, 534.

Year 1931

344. **Palacios, J. and Navarro, I.** Crystalline Structure of Barium Tungstate II, *Anales soc. españ. fís. quím.* 29, 21.

345. **Palacios, J. and Salvia, R.** Crystalline Structure of Argentite and Acanthite, *Anales. soc. españ. fís. quím.* 29, 269, 514.

346. **Parravano, N. and Cagliotti, V.** Alloys of Zinc and Manganese, *Rendiconti accad. Lincei* 14, 166.

347. **Passerini, L. and Baccaredda, M.** The Spinels IV. The Thiochromites of Manganese and Cadmium, *Rendiconti accad. Lincei* 14, 33.

348. **Pastorello, S.** Thermal Analysis of the System Lithium-Silver, *Gazz. chim. ital.* 61, 47.

349. **Patterson, A. L. and White, T. N.** The X-ray Investigation of Certain Derivatives of Cyclohexane I. General Survey, *Z. Krist.* 78, 760. 350. II. Quebrachitol, *ibid.* 78, 86.

351. **Pauling, L.** Quantum Mechanics and the Chemical Bond, *Phys. Rev.* 37, 1185. 352. The Nature of the Chemical Bond, Application of Results Obtained from the Quantum Mechanics and from a Theory of Paramagnetic Susceptibility to the Structure of Molecules, *J. Am. Chem. Soc.* 53, 1367. 353. II. The One-electron Bond and the Three-electron Bond, *ibid.* 53, 3225.

354. **Pauling, L. and Dickinson, R. G.** Objections to a Proof of Molecular Asymmetry of Optically Active Phenylaminoacetic Acid, *J. Am. Chem. Soc.* 53, 3820.

355. **Perlitz, H.** Change of the Distance between Adjacent Atoms in Certain Elements and Alloys that Results when the Cubic Face-centered Lattice Changes to the Cubic Body-centered or Hexagonal Lattice, *Acta Commentationes Univ. Tartu* XXIIA; *Trans. Faraday Soc.* 28, 514 (1932) 356. The Distribution of Crystal Structure Types of the Elements Arranged according to Long Periods, *Z. Krist.* 76, 473.

357. **Phillips, F. C.** Ephesite (Soda-margarite) from the Postmasburg District, South Africa, *Mineralog. Mag.* 22, 482.

358. **Phragmen, G.** X-ray Investigation of Certain Nickel Steels of Low Thermal Expansion, *J. Iron Steel Inst.* 123, 465.

359. **Pickup, L.** X-rays and Metallurgy, *Metallurgia* 3, 101, 108.

360. **Pierce, W. C.** The Effect of General Radiation in the Diffraction of X-rays by Liquids, *Phys. Rev.* 38, 1409. 361. Higher-order Effects in the Diffraction of X-rays by Liquids, *ibid.* 38, 1413.

362. **Posnjak, E. and Barth, T. F. W.** A New Type of Crystal Fine-structure: Lithium Ferrite ($Li_2O{\cdot}Fe_2O_3$), *Phys. Rev.* 38, 2234.

363. **Posnjak, E. and Bowen, N. L.** The Rôle of Water in Tremolite, *Am. J. Sci.* 22, 203.

364. **Prasad, M. and Mapara, H. M.** X-ray Investigation of the Crystals of Copper Formate Dihydrate, *Indian J. Physics* 6, 41.

365. **Preston, G. D.** An X-ray Investigation of Some Copper-Aluminum Alloys, *Phil. Mag.* 12, 980. 366. X-ray Examination of Gold-Copper Alloys, *J. Inst. Metals, Adv. copy.* No. 571, *Appendix*, 21. 367. X-ray Examination of the System: Silver-Mercury, *ibid.* 46, 522. 367a. X-ray Examination of Chromium-Iron Alloys. *J. Iron Steel Inst.* 124, 139.

368. **Prins, J. A.** Diffraction of X-rays in Liquids and Solutions of Ions, *Z. Physik* 71, 445. 369. Molecular Arrangement in Liquids and the Related Diffraction Phenomena, *Naturwiss.* 19, 435.

370. **Pummerer, R. and v. Susich, G.** Crystallized Rubber, *Kautschuk* 7, 117.

371. **Ray, K. W.** Platinum-Cadmium Alloys, *Proc. Iowa Acad. Sci.* 38, 166.

372. **Regler, F.** A New Calibration Method for the Precision Determination of Lattice Constants of Polycrystalline Materials, *Physikal. Z.* 32, 680. 373. A New Method for the Investigation of the Structure of Filaments and for the Detection of Internal Stresses in Technical Metals, *Z. Physik* 71, 371.

374. **Reinecke, R.** A Tetrahedrally Symmetrical Field of Influence as a General Structure Unit of all Crystal Lattices, *Z. Krist.* 78, 334. 375. Tetrahedral Field of Action of Atoms II. Nature of Secondary Valencies, *Ann. Guébhard-Séverine* 7, 174.

376. **Rheinboldt, H.** Constitutional Formulas of Crystalline Substances, *Z. anorg. Chem.* 200, 168.

377. **Rimington, C.** Protein Structure, *Trans. Faraday Soc.* 27, 222.

378. **Rinne, F.** Discussion of a Report on "Sperms as Living Liquid Crystals," *Centr. Mineral. Geol.* 1931A, 233.

379. **Rinne, F., Schiebold, E. and Sommerfeldt, E.** Report on Crystal Classes and

Year 1931
Space Groups of the Nomenclature Committee Appointed by the German Mineralogical Society, *Fortschr. Min. Krist. Pet.* 16, 39.

380. **Roseberry, H. H., Hastings, A. B. and Morse, J. K.** X-ray Analysis of Bone and Teeth, *J. Biol. Chem.* 90, 395.

381. **Ross, C. S. and Kerr, P. F.** The Kaolin Minerals, *U. S. Dept. Interior, Geol. Survey, Prof. Paper* 165-E.

382. **Ross, C. S., Henderson, E. P. and Posnjak, E.** Clarkeite: a New Uranium Mineral, *Am. Mineral.* 16, 213.

383. **Roussin, A. L. and Chesters, J. H.** Further Investigation of the Magnesia-Zircon Series Based on X-ray and Microscopic Examination, *Trans. Ceram. Soc. (England)* 30, 217.

384. **Rumpf, E.** Interferometric Spacing Measurements in Benzene and Carbon Tetrabromide Molecules by Means of X-rays, *Ann. Physik* 9, 704.

385. **Rusterholz, A.** The Scattering of X-rays by Metals, *Helv. Phys. Acta* 4, 68.

386. **Sachs, G. and Weerts, J.** Atom Arrangement and Properties, *Z. Physik* 67, 507.

387. **Sakisaka, Y. and Sumoto, I.** The Effects of the Thermal Strain on the Intensity of Reflection of X-rays by Some Crystals, *Proc. Phys.-Math. Soc. Japan 3rd Ser.* 13, 211.

388. **Saupe, E.** X-ray Diagrams of Human Tissues and Concretions, *Fortschr. Geb. Röntgenstrahlen* 44, 204.

389. **Sautner, K.** The System: Copper-Silicon, *Forschungsarb. Metallkunde Röntgenmetallographic* No. 9.

390. **Scherrer, P. and Staub, H.** X-ray Study of the Coagulation Process of Colloidal Gold, *Z. physik. Chem.* 154A, 309.

391. **Schiebold, E.** The Isomorphism of the Feldspar Minerals, *Neues Jahrb. Mineral. Geol. Beilage-Bd.* 64A, 251. 392. Remarks on the Proposals of E. Sommerfeldt, *Fortschr. Min. Krist. Pet.* 15, 45 (see 1931, 421).

393. **Schiebold, E. and Siebel, G.** Studies of Magnesium and its Alloys, *Mitt. deut. Materialprüfungsanstalt Sonderheft* 17, 61. 394. Studies of Magnesium and Magnesium Alloys, *Z. Physik* 69, 458.

395. **Schmid, E.** Contributions to the Physics and Metallography of Magnesium, *Z. Elektrochem.* 37, 447.

396. **Schmid, E. and Siebel, G.** X-ray Determination of the Solubility of Magnesium in Aluminum, *Z. Metallkunde* 23, 202. 397. The Determination of the Solubility of Manganese in Magnesium by X-rays, *Metallwirtschaft* 10, 923.

398. **Schmid, E. and Wassermann, G.** Recrystallization of Sheet Aluminum, *Metallwirtschaft* 10, 409. 399. The Texture of Rolled Cadmium, *ibid.* 10, 735.

400. **Schneider, E.** A New Graphic Method for Assigning Indices to Powder Photographs, *Z. Krist.* 78, 503.

401. **Schonefeld, P.** The Structure of Beryllium Sulfate Tetrahydrate, *Z. Krist.* 78, 16.

402. **Schramek, W. and Schubert, C.** The X-ray Fiber Diagram as a Quantitative Measuring Stick for Changes of Structural Units of Cellulose Fibers through Chemical Processes I. The Quantitative Relation between the Intensity of the Equatorial Interference of Known Combinations of Fibers of Native and Mercerized Cellulose, *Z. physik. Chem.* 13B, 462.

403. **Schramek, W., Schubert, C. and Velten, H.** Determination of the Alkali Consumption of Cellulose, *Cellulosechemie* 12, 126.

404. **Schusterius, C. A.** The Dimensions of the ClO_4 Group in Perchlorates, *Z. Krist* 76, 455.

405. **Schwarz, R. and Huf, E.** The Chemistry of Germanium VIII. Germanium Dioxide, *Z. anorg. Chem.* 203, 188.

406. **Scott, H.** Transformational Characteristics of Iron-Manganese Alloys, *Am. Inst. Min. Met. Eng. Tech. Pub.* No. 435.

407. **Seifert, H.** The Structure and (Oriented) Growth of Salts of the Type $R'PF_6$, *Fortschr. Min. Krist. Pet.* 15, 70. 408. The Structure and (Oriented) Growth of Salts of the Type $R'PF_6$, *Z. Krist.* 76, 455.

409. **Sekito, S.** On the X-ray Analysis of the Cementite Obtained by Tempering Quenched Steels, *Sci. Repts. Tôhoku Imp. Univ.* 20, 313. 410. A Quantitative Determination of Martensite and Austenite in Quenched and Tempered Steels by Means of X-ray Analysis, *ibid.* 20, 369. 411. X-ray Investigation of the Allotropic

Year 1931

Transformations of Manganese, Thallium and their Alloys, *Proc. World Eng. Cong. Tokyo 1929,* 36, 139.

412. **Sheppard, S. E.** Macromolecules and Micelles in Organic Polymers, *Ind. Eng. Chem.* 23, 781.

413. **Shiba, H. and Watanabê, T.** The Crystal Structures of Northupite, Brominated Northupite and Tychite, *Compt. rend.* 193, 1421.

414. **Shimura, S.** Study on Crystal Structure of Cementite, *Proc. World Eng. Cong. Tokyo 1929,* 34, 223; *J. Fac. Sci. Tokyo Imp. Univ.* 20, 1.

415. **Shôji, H.** Geometric Relationship between the Structures of the Modifications of a Substance, *Z. Krist.* 77, 381.

416. **Sisson, W. A.** X-ray Studies of Rolling and Heat Treatment of Sheet Metals, *Thesis, Univ. Illinois.*

417. **Slater, J. C.** Note on the Structure of the Groups XO_3, *Phys. Rev.* 38, 325.

418. **Smith, C. S.** X-ray Study of the Copper End of the Copper-Silver System, *Ind. Eng. Chem.* 23, 969.

419. **Smits, A.** The Complexity of Sulfur Trioxide, *Z. physik. Chem.* 152A, 432.

420. **Solomon, D. and Jones, W. M.** An X-ray Investigation of the Lead-Bismuth and Tin-Bismuth Alloys, *Phil. Mag.* 11, 1090.

421. **Sommerfeldt, E.** A Plan of the 230 Space Groups with Individual Symbols for their Structural Elements, *Fortschr. Min. Krist. Pet.* 15, 35. 422. Crystallographic Classification by Projection and Group-theory Methods, *ibid.* 15, 147.

423. **Sponsler, O. L. and Dore, W. H.** The Crystal Structure of Some Forms of Glucose, *J. Am. Chem. Soc.* 53, 1639.

424. **Spychalski, R.** Investigations on the Internal Structure of Soap Micelles by Means of X-rays, *Roczniki Chem.* 11, 427 (439 in German).

425. **v. Stackelberg, M.** The Crystal Structures of Several Carbides and Borides, *Z. Elektrochem.* 37, 542.

426. **Stenbeck, S. and Westgren, A.** X-ray Analysis of Gold-Tin Alloys, *Z. physik. Chem.* 14B, 91.

427. **Stenzel, W. and Weerts, J.** Lattice Constants of Silver-Palladium and Gold-Palladium Alloys, *Siebert Festschrift* 1931, 288. 428. X-ray Examination of Alloys of the Gold-Platinum System, *ibid.* 1931, 300.

429. **Stephen, R. A.** A New Self-contained X-ray Apparatus for Crystal Analysis, *J. Sci. Instruments* 8, 385.

430. **Stewart, G. W.** X-ray Diffraction in Water: The Nature of Molecular Association, *Phys. Rev.* 37, 9. 431. An X-ray Study of the Magnetic Character of Liquid Crystalline p-Azoxyanisole and a Comparison with the Isotropic Liquid, *ibid.* 38, 931. 432. Comparison of Viscosity and Molecular Arrangement in Twenty-two Liquid Octyl Alcohols, *ibid.* 38, 2082. 433. The Viscosity of Liquids, *Nature* 128, 727.

434. **Stewart, G. W. and Edwards, R. L.** Comparison of Viscosity and Molecular Arrangement in Twenty-two Liquid Octyl Alcohols, *Phys. Rev.* 38, 1575.

435. **Stillwell, C. W.** An X-ray Diffraction Study of Chicle, *Ind. Eng. Chem.* 23, 703. 436. Crystal Structures of Electrodeposited Alloys. Silver-Cadmium, *J. Am. Chem. Soc.* 53, 2416. 437. Recent Developments in the Application of X-rays to Chemistry and Industry, *Trans. Illinois State Acad. Sci.* 24, 252.

438. **Stillwell, C. W. and Clark, G. L.** Further X-ray Studies of Gutta-percha and Balata, *Ind. Eng. Chem.* 23, 706.

439. **Tamaru, K. and Sekito, S.** On the Quantitative Determination of Retained Austenite in Quenched Steels, *Sci. Repts. Tôhoku Imp. Univ.* 20, 377.

440. **Tanaka, K. and Kamio, K.** Mechanical Twins in White Tin and Zinc, *Mem. Coll. Sci. Kyoto Imp. Univ.* 14A, 79.

441. **Tanaka, S., Okuno, G. and Tsuji, A.** X-ray Diffraction of Some Organic Substances in the Solid and Liquid States, *Mem. Coll. Sci. Kyoto Imp. Univ.* 14A, 67.

442. **Taylor, N. W.** An X-ray Camera for Powder Diagrams at Any Temperature, *Rev. Sci. Instruments* 2, 751.

443. **Taylor, W. H. and Náray-Szabó, St.** The Structure of Apophyllite, *Z. Krist.* 77, 146.

444. **Theilacker, W.** The Crystal Structure of Guanidinium Chloride, *Z. Krist.* 76, 303.

445. **Thewlis, J.** The Structure of Ferromagnetic Ferric Oxide, *Phil. Mag.* 12, 1089.

446. **Timmermans, J.** The Relation between Some Physical Properties of Organic

Year 1931

Molecules and their Constitution and Configuration, *Inst. intern. chim. Solvay, Conseil chim.* 4, 191.

447. **Trillat, J. J.** I. Structure of Films. Transformations of the Lattice of Cellulose Nitrate Film. II. Structure of Nitrated and Acetylated Cotton, *J. phys. rad.* 2, 65.

448. **Trillat, J. J. and Forestier, J.** Study of the Structure of Plastic Sulfur, *Compt. rend.* 192, 559.

449. **Trillat, J. J. and Nowakowski, A.** Researches on the Formation of Thin Films of Organic Compounds and Phenomena Accompanying the Formation, *Ann. phys.* 15, 455.

450. **Trogus, C. and Hess, K.** X-ray Investigations of Cellulose Derivatives IX. The X-ray Diagram of Trinitrocellulose—a Contribution to the Knowledge of Stabilization Changes, *Z. physik. Chem.* 12B, 268. 451. XI. Additive Compounds of Cellulose with Hydrazine, Ethylenediamine and Tetramethylenediamine, *ibid.* 14B, 387.

452. **Tunell, G. and Posnjak, E.** A Portion of the System: Ferric Oxide-Cupric Oxide-Sulfur Trioxide-Water, *J. Phys. Chem.* 35, 929.

453. **Turner, H. G. and Anderson, H. V.** A Microscopical and X-ray Study of Pennsylvania Anthracite, *Ind. Eng. Chem.* 23, 811.

454. **Vegard, L.** The Structure of Solid N_2O_4 at the Temperature of Liquid Air, *Z. Physik* 68, 184. 455. The Crystal structure of N_2O_4, *ibid.* 71, 299. 456. The Structure of Solid Hydrogen Sulfide and Hydrogen Selenide at the Temperature of Liquid Air, *Z. Krist.* 77, 23. 457. The Structure of Solid COS at the Temperature of Liquid Air, *ibid.* 77, 411. 458. Mixed-crystal Formation in Molecular Lattices by Irregular Exchange of Molecules, *Naturwiss.* 19, 443. 459. Mixed-crystal Formation in Molecular Lattices by Means of Exchange of Molecules, *Z. Physik* 71, 465.

460. **Vegard, L. and Bilberg, L.** The Crystal Structure of Nitrates of Calcium, Strontium, Barium and Lead, *Norske Videnskaps-Akad. Oslo I. Mat. naturv. Kl.* 1931, No. 12.

461. **Verweel, H. J. and Bijvoet, J. M.** The Crystal Structure of Mercury Bromide, *Z. Krist.* 77, 122.

462. **Vigfusson, V. A.** The Hydrated Calcium Silicates II. Hillebrandite and Foshagite, *Am. J. Sci.* 21, 73.

463. **Wagner, H.** Hydroxide Systems in Iron Oxide Colors, *Kolloid-Z.* 54, 310.

464. **Warren, B. E. and Biscoe, J.** The Crystal Structure of the Monoclinic Pyroxenes, *Z. Krist.* 80, 391.

465. **Warren, B. E. and Modell, D. I.** The Structure of Vesuvianite, *Z. Krist.* 78, 422.

466. **Weiser, H. B. and Milligan, W. O.** The Transformation from Rose to Green Manganous Sulfide, *J. Phys. Chem.* 35, 2330.

467. **Westgren, A.** Martensite. Recent Structural Studies, *Metal Progress* 20, No. 2, 49. 468. High-Chromium Steels, *ibid.* 20, No. 5, 57. 469. X-ray Determination of Alloy Equilibrium Diagrams, *Trans. Am. Inst. Min. Met. Eng., Inst. Metals Div.* 93, 13. 470. Crystal Structure and Atomic Properties of Alloys Containing Transition Elements, *J. Franklin Inst.* 212, 577.

471. **White, T. N.** The X-ray Investigation of Certain Derivatives of Cyclohexane III. l-Inositol, i-Inositol and Quercitol, *Z. Krist.* 78, 91. 472. IV. i-Inositol Dihydrate, *ibid.* 80, 1. 473. V. α- and γ-Cyclohexandiol 1, 2, β-Cyclohexandiol 1, 4 (trans-Quinitol), and β-Cyclohexandiacetate 1, 4, *ibid.* 80, 5.

474. **Williams, E. H.** Magnetic Properties of Copper-Nickel Alloys, *Phys. Rev.* 38, 828.

475. **Wollan, E. O.** Note on Scattering by Diatomic Gases, *Proc. Natl. Acad. Sci.* 17, 475. 476. Scattering of X-rays from Gases, *Phys. Rev.* 37, 862. 477. Experimental Electron Distributions in Atoms of Monatomic Gases, *ibid.* 38, 15.

478. **Woo, Y. H.** Temperature and Diffuse Scattering of X-rays from Crystals, *Phys. Rev.* 38, 6. 479. The Intensity of Total Scattering of X-rays by Gases, *Proc. Natl. Acad. Sci.* 17, 467. 480. Intensity of Total Scattering of X-rays by Monatomic Gases, *Sci. Repts. Natl. Tsing Hua Univ.* 1A, 55. 481. Scattering of X-rays by Mercury Vapor, *Nature* 127, 556.

482. **Wood, W. A.** Anomalous X-ray Diffraction Intensities, *Nature* 127, 703. 483. The Influence of the Crystal Orientation of the Cathode on that of an Electrodeposited Layer, *Proc. Phys. Soc. London* 43, 138.

Year 1931

484. **Wooster, N.** Crystal Structure of Molybdenum Trioxide, *Nature* 127, 93. 485. The Crystal Structure of Molybdenum Trioxide, *Z. Krist.* 80, 504.

486. **Wooster, W. A.** On the Relation between Double Refraction and Crystal Structure, *Z. Krist.* 80, 495.

487. **Wooster, W. A. and Wooster, N.** Crystal Structure of Chromium Trioxide, *Nature* 127, 782.

488. **Wyart, J.** Chabazite, *Compt. rend.* 192, 1244. 489. Crystal Structure of Thomsonite and Natrolite, *ibid.* 193, 666.

490. **Wyckoff, R. W. G.** "The Structure of Crystals," 2nd Ed. New York (1931).

491. **Yoshida, U. and Matsumoto, N.** X-ray Diffraction Pattern of Native Cellulose, *Mem. Coll. Sci. Kyoto Imp. Univ.* 14A, 115.

492. **Young, J. and Spiers, F. W.** A Determination of the Space Groups of Certain Carbohydrates, *Z. Krist.* 78, 101.

493. **Zachariasen, W. H.** Meliphanite, Leucophanite and their Relation to Melilite, *Norsk geol. tidss.* 12, 577. 494. The Crystal Lattice of Calcium Metaborate, *Proc. Natl. Acad. Sci.* 17, 617. 495. The Crystalline Structure of Hambergite, $Be_2BO_3(OH)$, *Z. Krist.* 76, 289. 496. A Set of Empirical Crystal Radii for Ions with Inert Gas Configuration, *ibid.* 80, 137. 497. The Structure of Groups XO_3 in Crystals, *J. Am. Chem. Soc.* 53, 2123. 498. Note on the Structure of Groups in Crystals, *Phys. Rev.* 37, 775.

499. **Zachariasen, W. H. and Barta, F. A.** Crystal Structure of Lithium Iodate, *Phys. Rev.* 37, 1626.

500. **Zachariasen, W. H. and Buckley, H. E.** Crystal Lattice of Anhydrous Sodium Sulfite, *Phys. Rev.* 37, 1295.

501. **Zachariasen, W. H. and Ziegler, G. E.** The Crystal Structure of Potassium Chromate, *Z. Krist.* 80, 164.

502. **Zedlitz, O.** The Crystal State of Biphenylenediphenylethylene (I), Biphenylenediphenylethylene Oxide (II), and the "Mixed Crystals" between Them, *Ber.* 64B, 2424.

503. **Zeidenfeld, S.** The Hilger X-ray Crystallograph and the Cubic Crystal Analyzer, *Proc. Phys. Soc. London* 43, 512.

504. **Ziegler, G. E.** Crystal Structure of Sodium Nitrite, *Phys. Rev.* 38, 1040.

505. **Zintl, E. and Harder, A.** Polyplumbides and Polystannides in Metallic Phases, *Z. physik. Chem.* 154A, 47.

506. **Zintl, E., Harder, A. and Neumayr, S.** Preparation of Alloys Sensitive to Air for Debye-Scherrer Diagrams, *Z. physik. Chem.* 154A, 92.

507. **Zwicky, F.** Supplementary Note to my Paper: The Mosaic Structure of Crystals, *Helv. Phys. Acta* 4, 49.

508. **Brentano, J.** On the Method of Directly Photometering Weak Blackenings and its Use in the Evaluation of X-ray F-Values. *Z. physik* 70, 74.

509. **Tutiya, H.** Catalytic Decomposition of Carbon Monoxide IV. Behavior of Nickel Carbides, *Bull. Inst. Phys. Chem. Research (Tokyo)* 10, 951.

Year 1932

1. **Abel, E., Adler, J., Halla, F. and Redlich, O.** The Crystal Structures of the Compounds in the Systems Sb-Cd, *Z. anorg. Chem.* 205, 398.

2. **Acken, M. F., Singer, W. E. and Davey, W. P.** X-ray Study of Rubber Structure, *Ind. Eng. Chem.* 24, 54.

3. **Agar, W. M. and Krieger, P.** Garnet Rock near West Redding, Conn., *Am. J. Sci.* 24, 68.

4. **Agte, C., Becker, K. and v. Göler, F.** The Tungsten-Cobalt System, *Metallwirtschaft* 11, 447.

5. **Akimov, G. V. and Oleshko, A. S.** The Structural Corrosion of Aluminum Alloys I. Electrode Potentials of the Structural Components of Aluminum Alloys, *J. Phys. Chem. (U.S.S.R.)* 3, 336.

5a. **Albright, J. G.** The Crystal Structure of Lithium Sulfate, *Z. Krist.* 84, 150.

6. **Allard, G.** X-ray Study of Some Borides, *Bull. soc. chim. France* 51, 1213.

7. **Anderson, B. W.** The Use of X-rays in the Study of Pearls, *Brit. J. Radiology* 5, 57.

8. **Arnfelt, H.** On the Formation of Layer-lattices, *Arkiv. Mat. Astron. Fysik* 23B, No. 2.

9. **Astbury, W. T.** X-ray Diffraction Photographs of Vegetable and Animal Fibers, *Photographic J.* 72, 318.

Year 1932

10. **Astbury, W. T., Henry, D. C., Rideal, E. K. and Schofield, R. K.** Colloid Chemistry, *Ann. Repts. Chem. Soc. for 1931,* 28, 322.

11. **Astbury, W. T. and Marwick, T. C.** X-ray Interpretation of the Molecular Structure of Feather Keratin, *Nature* 130, 309.

12. **Astbury, W. T., Marwick, T. C. and Bernal, J. D.** X-ray Analysis of the Structure of the Wall of *Valonia ventricosa* I, *Proc. Roy. Soc. (London)* 109B, 443.

13. **Astbury, W. T. and Woods, H. J.** The Molecular Structure of Textile Fibers, *J. Textile Inst.* 23, 117.

14. **Baccaredda, M.** The Structure of Spherocobaltite, *Rendiconti accad. Lincei* 16, 248.

15. **Bain, E. C., Davenport, E. S. and Waring, W. S. N.** The Equilibrium Diagram of Iron-Manganese-Carbon Alloys of Commercial Purity, *Trans. Am. Inst. Min. Met. Eng.* 100, 228.

16. **Bannister, F. A.** The Distinction of Pyrite from Marcasite in Nodular Growths, *Mineralog. Mag.* 23, 179. 17. Determination of Minerals in Platinum Concentrates from the Transvaal by X-ray Methods, *ibid.* 23, 188.

18. **Barlett, H. B.** Occurrence and Properties of Crystalline Alumina in Silicate Melts, *J. Am. Ceram. Soc.* 15, 361.

19. **Barnes, W. H. and Hunter, R. G.** Confirmation of the Space Groups of Epsomite, *Nature* 130, 96.

20. **Baroni, A.** Alloys of Lithium. Thermal and X-ray Analysis of the System: Lithium-Tin, *Rendiconti accad. Lincei* 16, 153.

21. **Barrett, C. S. and Howe, C. E.** X-ray Reflection from Inhomogeneously Strained Quartz, *Phys. Rev.* 39, 889.

22. **Barth, T. F. W.** Structures Having Non-equivalent Atoms in Equivalent Positions, *Fortschr. Min. Krist. Pet.* 17, 25. 23. The Chemical Composition of Noselite and Haüyne, *Am. Mineral.* 17, 466. 24. The Cristobalite Structures I. High-cristobalite, *Am. J. Sci.* 23, 350. 25. II. Low-cristobalite, *ibid.* 24, 97. 26. The Structures of the Minerals of the Sodalite Family, *Z. Krist.* 83, 405.

27. **Barth, T. F. W. and Posnjak, E.** Silicate Structures of the Cristobalite Type I. The Crystal Structure of α-Carnegieite ($NaAlSiO_4$), *Z. Krist.* 81, 135. 28. II. The Crystal Structure of Na_2CaSiO_4, *ibid.* 81, 370. 29. III. Structural Relationship of High-cristobalite, α-Carnegieite and Na_2CaSiO_4, *ibid.* 81, 376. 30. Spinel Structures, with and without Variate Atom Equipoints, *ibid.* 82, 325.

31. **Beevers, C. A. and Lipson, H.** The Crystal Structure of Beryllium Sulfate Tetrahydrate, *Z. Krist.* 82, 297. 32. The Crystal Structure of Nickel Sulfate Hexahydrate, *ibid.* 83, 123.

33. **Belladen, L.** The Cathodic Pulverization of Metal Alloys IV, *Gazz. chim. ital.* 62, 497.

34. **Berg, W.** Asterisms in X-ray Diagrams, *Z. Krist.* 83, 318.

35. **Berl, E., Andress, K., Reinhardt, L. and Herbert, W.** Nature of Activated Carbons, *Z. physik. Chem.* 158A, 273.

36. **Berman, H. and West, C. D.** Fibrous Brucite from Quebec. Note on its Structure after Dehydration, *Am. Mineral.* 17, 313.

37. **Bernal, J. D.** A Crystallographic Examination of Oestrin, *J. Soc. Chem. Ind.* 51, *Chem. Ind.* 259. 38. Carbon Skeleton of the Sterols, *ibid.* 51, *Chem. Ind.* 466. 39. Crystal Structures of Vitamin D and Related Compounds, *Nature* 129, 277. 40. Properties and Structures of Crystalline Vitamins, *ibid.* 129, 721. 41. Rotation of Carbon Chains in Crystals, *Z. Krist.* 83, 153. 42. Rotation of Molecules in Crystals, *Nature* 129, 870. 43. Crystal Structure of Complex Organic Compounds, *Lecture Delivered at Univ. of Manchester July 13,* 1932. 44. The Significance of X-ray Crystallography in the Development of Modern Science, *Uspekhi Khim.* (*Progress Chem. U.S.S.R.*) 1, 273.

45. **Bernal, J. D. and Wooster, W. A.** Crystallography (1930-31), *Ann. Repts. Chem. Soc. for 1931,* 28, 262.

46. **Berthold, R. and Böhm, H.** An X-ray Diffraction Chamber for Investigations at Elevated Temperatures, *Metallwirtschaft* 11, 567.

47. **Bewilogua, L.** The Scattering of X- and Cathode Rays by Free Molecules, *Physikal. Z.* 33, 688.

48. **Bijvoet, J. M. and Karssen, A.** Crystal Structure of Lithium Hydride, *Z. physik. Chem.* 15B, 414. (See also Reply, **Zintl, E. and Harder, A.** *ibid.* 15B, 416).

49. **Bijvoet, J. M. and Ketelaar, J. A. A.** Molecular Rotation in Solid Sodium Nitrate, *J. Am. Chem. Soc.* 54, 625.

Year 1932

50. **Bird, P. H.** A New Occurrence and X-ray Study of Mosesite, *Am. Mineral.* 17, 541.

51. **Birckenbach, L. and Buschendorf, F.** Preparation and Crystal Structure of Normal (meta) Silver Periodate, *Z. physik. Chem.* 16B, 102.

52. **Boas, W.** Determination of the Solubility of Cadmium in Zinc by X-rays, *Metallwirtschaft* 11, 603.

53. **Boas, W. and Schmid, E.** The Structure of the Surface of Polished Metal Crystals, *Naturwiss.* 20, 416.

54. **Boehm, G. and Weber, H. H.** The X-ray Diagram of Stretched Myosin Fibers, *Kolloid-Z.* 61, 269.

55. **Boetticher, M.** The Investigation of the Heat Conductivity of Refractory Materials with Particular Consideration of Magnesite Bricks, *Mitt. Forsch.-Inst. Ver. Stahlwerke A.-G. Dortmund* 2, 235; *Metals and Alloys* 3, *Abstr.* 360.

56. **Borisov, N. D.** Methods for Evaluation of X-ray Photographs, *J. Tech. Phys.* (*U.S.S.R.*) 2, 501.

57. **Born, M. and Mayer, J. E.** The Lattice Theory of Ion Crystals, *Z. Physik* 75, 1.

58. **Bottema, J. A. and Jaeger, F. M.** On the Law of Additive Atomic Heats in Intermetallic Compounds IX. The Compounds of Tin and Gold, and of Gold and Antimony, *Proc. Acad. Sci. Amsterdam* 35, 916.

59. **Bowen, E. G. and Morris-Jones, W.** An X-ray Investigation of the Bismuth-Antimony Alloys, *Phil. Mag.* 13, 1029.

60. **Bozorth, R. M. and Pauling, L.** The Crystal Structure of Magnesium Platinocyanide Heptahydrate, *Phys. Rev.* 39, 537.

61. **Bradley, A. J. and Hope, R. A. H.** The Atomic Scattering Power of Iron for various X-ray Wave Lengths, *Proc. Roy. Soc.* (*London*) 136A, 272.

62. **Bradley, A. J. and Jay, A. H.** A Method for Deducing Accurate Values of the Lattice Spacing from X-ray Powder Photographs Taken by the Debye-Scherrer Method, *Proc. Phys. Soc. London* 44, 563. 63. The Lattice Spacings of Iron-Aluminum Alloys, *J. Iron Steel Inst.* 125, 339. 64. The Formation of Superlattices in Alloys of Iron and Aluminum, *Proc. Roy. Soc.* (*London*) 136A, 210.

65. **Bradley, A. J. and Roussin, A. L.** An X-ray Study of Porcelains and their Relation to Mullite, *Trans. Ceram. Soc.* (*England*) 31, 422.

66. **Braekken, H.** The Crystal Structure of Mercuric Bromide, *Z. Krist.* 81, 152. 67. A Universal X-ray Apparatus for Crystal Structure Investigations, *ibid.* 81, 309. 68. The Crystal Structure of Chromium Tribromide, *Kong. Norske Videnskabers Selskab Forh.* 5, No. 11. 69. The Crystal Structure of Lead Chloride, *Z. Krist,* 83, 222.

70. **Brandenberger, E.** The Crystal Structure of Beryllium Fluoride, *Schweiz. Mineralog.-Petrograph. Mitt.* 12, 243.

71. **Brasseur, H.** Contribution to the Structure of Malachite, *Z. Krist.* 82, 111. 72. The Structure of Azurite, *ibid.* 82, 195. 73. Structures and Optical Properties of the Carbonates, *Actualités sci. ind. Ser.* 1932, No 51.

74. **Braunbek, W.** Relations between Empirical Atomic and Ionic Radii and the Charge Distribution in the Atom according to Thomas-Fermi, *Z. Physik* 79, 701.

75. **Brill, R.** The Lattice Constants of α-Fe_2O_3 and γ-Al_2O_3, *Z. Krist.* 83, 323. 76. X-ray Investigation of Iron as a Catalyst in the Synthesis of Ammonia, *Z. Elektrochem.* 38, 669.

77. **Brill, R. and Haag, W.** Mercury Compounds of Iron and Nickel, *Z. Elektrochem.* 38, 211.

78. **Brindley, G. W.** Relation of Atomic Sizes to Interatomic Distances in Homopolar Crystals, *Z. Krist.* 84, 169. 79. On the Intensity of Reflection of X-rays by Perfect Crystals, *Proc. Leeds Phil. Soc., Sci. Sect.* 2, 271. 80. On the Refraction of X-rays by Perfect Crystals, *ibid. Sci. Sect.* 2, 319.

81. **Brownmiller, L. T. and Bogue, R. H.** System: CaO-Na_2O-Al_2O_3, *Bur. Standards J. Res.* 8, 289.

82. **Brückl, K.** The Structure of d-Pseudococaine l-Ephedrine d-Tartrate and d-Pseudococaine l-Methylephedrine d-Tartrate, *Z. Krist.* 81, 219.

83. **Buerger, M. J.** The Crystal Structure of Löllingite, *Z. Krist.* 82, 165.

84. **Burgers, W. G.** The Crystal Structure of β-Zirconium, *Z. anorg. Chem.* 205, 81. 85. Crystal Structure of β-Zirconium, *Nature* 129, 281. 86. The Relation between Deformation Structure and Recrystallization Structure of Aluminum, *Metallwirtschaft* 11, 251, 265.

Year 1932

87. **Burgers, W. G., Claassen, A. and Zernike, J.** The Chemical Nature of Oxide Layers that are Formed by Anodic Polarization on the Metals Aluminum, Zirconium, Titanium and Tantalum, *Z. Physik* 74, 593.

88. **Bury, C. R. and Davies, E. R. H.** System: Magnesium Oxide-Magnesium Chloride-Water, *J. Chem. Soc.* 1932, 2008.

89. **Buschendorf, F.** Minerogenetic Habit Studies of Recent Barite Formations, *Z. Krist.* 81, 38.

90. **Caglioti, V. and Roberti, G.** X-ray Investigation of a Subsulfide of Cobalt Employed as a Catalyst in the Hydrogenation of Phenol, *Gazz. chim. ital.* 62, 19.

91. **Caglioti, V. and Sachs, G.** The Structure of Rolled Zinc and Magnesium, *Metallwirtschaft* 11, 1.

92. **Cameron, G. H.** X-ray Method of Determining the Sizes of Submicroscopic Crystals, *Physics* 3, 57.

93. **Canneri, G. and Rossi, A.** The Preparation of Metallic Praseodymium, *Gazz. chim. ital.* 62, 1160.

94. **Carlsson, O. and Hägg, G.** The Crystal Structure of some phases of Copper-Tin, *Z. Krist.* 83, 308.

95. **Carter, J. H.** I. An X-ray Investigation of the Iron-Copper System. II. A Study of the Corrosion of Galvanized Sheet Iron, *Iowa State Coll. J. Sci.* 6, 413.

96. **Caspari, W. A.** Crystallography of the Simpler Quinones, *Proc. Roy. Soc. (London)* 136A, 82.

97. **Cauchois, Y.** A New Method for the Analysis of Crystalline Powders by X-rays, Using a Curved Crystal Monochromator, *Compt. rend.* 195, 228.

98. **Champetier, G. and Thuau, U. V.** The Dehydration of Cupric Hydroxide, *Compt. rend.* 194, 93.

99. **Chesley, K. G., Anderson, H. V. and Theis, E. R.** X-ray Studies of Animal Skin I. Structure of Calfskin as Indicated by Molybdenum Radiation, *J. Am. Leather Chem. Assoc.* 27, 12.

100. **Chrobak, L.** "Backward-reflecting" Laue Photographs, *Z. Krist.* 82, 342.

101. **Clark, G. L.** Remarks on the Work: Lattice Dimensions of Spinels, *Z. physik. Chem.* 17B, 463. 102. X-rays as a Research Tool in Chemistry and Industry, *Ind. Eng. Chem.* 24, 182. 103. X-rays and Sugar, *Proc. 4th Cong. Intern. Soc. Sugar Cane Tech., Bull.* No. 97.

104. **Clark, G. L. and Ally, A.** X-ray Examination of Chrome Ores I. Lattice Dimensions. II. Theoretical Densities, *Am. Mineral.* 17, 66.

105. **Clark, G. L. and Corrigan, K. E.** The Crystal Structure of Insulin, *Phys. Rev.* 40, 639.

106. **Clouse, J. H.** Investigations on the X-ray Crystal Structures of $CaCrO_4$, $CaCrO_4 \cdot H_2O$ and $CaCrO_4 \cdot 2H_2O$, *Z. Krist.* 83, 161.

107. **Cork, J. M.** Variation in the Effective Lattice Constant of Crystals with Wave Lengths, *Phys. Rev.* 39, 193. 108. Laue Patterns from Thick Crystals at Rest and Oscillating Piezoelectrically, *ibid.* 42, 749.

109. **Corriez, M.** X-rays and the Evolution of Chemistry I. Absorption and Refraction of X-rays. II. Diffraction of X-rays by Crystals. III. Application to the Study of Organic Compounds, *J. pharm. chim.* 16, 436, 483, 530.

110. **Coster, D. and Knol, K. S.** The Atomic Factor for X-rays in the Region of Anomalous Dispersion, *Z. Physik* 75, 340.

111. **Coster, D. and v. d. Ziel, A.** An X-ray Investigation of the n-Monoalkyl Malonic Acids, *Proc. Acad. Sci. Amsterdam* 35, 91.

112. **Coven, A. W.** Scattering of X-rays from Solids, *Phys. Rev.* 41, 422.

113. **Cox, E. G.** An X-ray Examination of β-Methylxyloside, *J. Chem. Soc.* 1932, 138. 113a. The Crystalline Structure of β-Arabinose, *Z. Krist.* 84, 45. 114. The Crystalline Structure of Tetramminoplatinous Chloride, *J. Chem. Soc.* 1932, 1912. 115. Crystalline Structure of α-Methylxyloside, *ibid.* 1932, 2535. 116. Crystalline Structure of Hexuronic Acid, *Nature* 130, 205. 117. Crystalline Structure of Benzene, *Proc. Roy. Soc. (London)* 135A, 491.

118. **Cox, E. G. and Goodwin, T. H.** X-ray Evidence of the Structure of the Furanose and Pyranose Forms of α-Methylmannoside, *J. Chem. Soc.* 1932, 1844.

119. **Cox, E. G., Pinkard, F. W., Wardlaw, W. and Preston, G. H.** The Green Salt of Magnus and Some Related Compounds, *J. Chem. Soc.* 1932, 2527.

120. **Darbyshire, J. A.** An X-ray Examination of the Oxides of Lead, *J. Chem. Soc.* 1932, 211.

121. **Deflandre, M.** Crystal Structure of Diaspore, *Bull. soc. franç. min.* 55, 140.

Year 1932

122. **Dehlinger, U.** Electronic Structure and Properties of Metals, *Z. Elektrochem.* 38, 148.

123. **Dehlinger, U. and Giesen, F.** The Connection between Regular Atom Distribution and Resistance Limits, *Z. Metallkunde* 24, 197.

124. **Delaunay, B.** New Representation of Geometrical Crystallography I, *Z. Krist.* 84, 109.

125. **Derksen, J. C.** Crystallization and the Setting of Gelatin Jellies, *Collegium* 1932, 838.

126. **Derksen, J. C. and Katz, J. R.** X-ray Studies of the Gel Formation of Starch Sols, *Rec. trav. chim.* 51, 523.

127. **Desmaroux and Mathieu.** The Structure of Nitrocellulose Films which Contain a High Percentage of Nitrogen, *Compt. rend.* 194, 2053. 128. The Structure of Films of Highly Nitrated Cellulose, *ibid.* 195, 242.

129. **Dhar, J.** X-ray Analysis of the Structure of Diphenyl, *Indian J. Physics* 7, 43.

130. **Drugman, J. and Hey, M. H.** Legrandite, a New Zinc Arsenate, *Mineralog. Mag.* 23, 175.

131. **Dupré la Tour, F.** X-ray Study of the Polymorphism of Normal Saturated Fatty Acids, *Thesis, Univ. Paris June 21.* 132. Study of the Dimorphism of Normal Saturated Aliphatic Dicarboxylic Acids as a Function of Temperature, *Compt. rend.* 194, 622. 133. X-ray Study of the Polymorphism of the Normal Saturated Acids of the Aliphatic Series, *Ann. phys.* 18, 199.

134. **Dwyer, F. P. J. and Mellor, D. P.** Crystal Structure of Indium, *J. Proc. Roy. Soc. N. S. Wales* 66, 234. 135. The Occurrence of β-Cristobalite in Australian Opals, *ibid.* 66, 378.

136. **Eddy, C. E.** A Self-rectifying Demountable X-ray Tube of High Power, *J. Sci. Instruments* 9, 354.

137. **Egartner, L., Halla, F. and Schacherl, R.** Determination of Structure of the Aromatic Disulfides and Diselenides R–S(Se)–S(Se)–R, ($R{=}C_6H_5$, $C_6H_5CH_2$, C_6H_5CO), *Z. physik. Chem.* 18B, 189.

138. **Egartner, L., Halla, F. and Schwarz, E.** The Space Lattice of Hydrated Cadmium Sulfate, $CdSO_4.\frac{8}{3}H_2O$, *Z. Krist.* 83, 422.

139. **Ehrenberg, W. and Schäfer, K.** Report on Atomic Structure Factors, *Physikal. Z.* 33, 97. 140. Supplement to the Report on Atomic Structure Factors, *ibid.* 33, 575.

141. **Ehrhardt, F.** X-ray Interference by Molecules with Two Carbon Atoms, *Physikal. Z.* 33, 605.

142. **Eissner, W. and Brill, R.** Note on our Work: Crystallographic and X-ray Investigations of Hexabromobutylene, *Z. Krist.* 81, 316.

143. **Eitel, W.** Constitution of Silicates in the Light of Crystallographic Investigations of the Structure, *Glashütte* 62, 410; *Sprechsaal* 65, 552.

144. **Ernst, Th.** Crystal Structure of Lithium Hydroxide, *Naturwiss.* 20, 124.

145. **Evjen, H. M.** The Effect of a Secondary Structure upon the Interference of X-rays, *Phys. Rev.* 41, 265.

146. **Ewald, P. P.** The Discovery of X-ray Interference 20 Years Ago and Sir Wm. Bragg's Seventieth Birthday, *Naturwiss.* 20, 527.

146a. **Feitknecht, W.** The Structure of α-Zinc Hydroxide, *Z. Krist.* 84, 173.

147. **Ferrari, A. and Curti, R.** The Habit and Crystal Structure of Potassium Bitartrate, *Z. Krist.* 84, 8.

148. **Fink, W. L. and Van Horn, K. R.** Equilibrium Relations in Aluminum-Zinc Alloys of High Purity, *Am. Inst. Min. Met. Eng., Inst. Metals Div., Tech. Pub.* **No.** 474.

149. **Fox, G. W.** An Oscillator for the Crystal of an X-ray Spectrograph, *Rev. Sci. Instruments* 3, 71.

150. **Foz, O. R. and Palacios, J.** The Structure of Ordinary Quinhydrone, *Anales soc. españ. fís. quím.* 30, 421.

151. **Freudenberg, K.** The Relation of Cellulose to Lignin in Wood, *Papier-Fabr.* 30, *Tech.-Wiss. Teil* 189; *J. Chem. Education* 9, 1171.

152. **Fricke, R. and Ackermann, P.** Existence of Lead Suboxide, *Z. physik. Chem.* 161A, 227.

153. **Fricke, R. and Severin, H.** The Dissociation Pressures of Crystalline Hydroxides, Particularly those of Aluminum and Beryllium, *Z. anorg. Chem.* 205, 287.

154. **Fujiwara, T.** Effects of the Direction of Drawing on the Arrangement of

the Micro Crystals in Aluminum Wire and on its Tensile Strength and Broken Fracture, *Mem. Coll. Sci. Kyoto Imp. Univ.* 15A, 35.

155. Garbsch, P. and v. Susich, G. X-ray Investigation of μ-Polychloroprene, $(CH_2{:}CClCH{:}CH_2)_x$, *Kautschuk* 8, 122.

156. Garrido, J. Crystallographic X-ray Study of Kernite, $Na_2B_4O_7.4H_2O$, *Anales soc. españ. fís. quím.* 30, 91. **157.** The Symmetry and Space Group of Kernite, *Z. Krist.* 82, 468. **158.** Crystalline Structure of Ammonium Iodate, *Anales soc. españ. fís. quím.* 30, 811.

159. Gerngross, O., Herrmann, K. and Lindemann, R. Reversible Sol-Gel Transformation, Crystallization of Gelatin and the Fine Structure of Elastic Gels, Especially of Gelatin and Rubber in the Light of X-ray Optics, *Kolloid-Z.* 60, 276.

160. Glocker, R. Lattice-binding Forces and X-ray Spectrum, *Naturwiss.* 20, 536.

161. Glocker, R. and Graf, L. The Dependence of Tamman's Resistance Limits on the Crystallographic Orientation, *Metallwirtschaft* 11, 226.

162. Goetz, A. and Hergenrother, R. C. X-ray Studies on Bismuth Single Crystals, *Phys. Rev.* 40, 137. **163.** X-ray Studies of the Thermal Expansion of Bismuth Single Crystals, *ibid.* 40, 643.

164. Goldschmidt, V. M. The Rutile Modification of Germanium Dioxide, *Z. physik. Chem.* 17B, 172. **165.** Lattice Constants of the Spinels $MgAl_2O_4$ and $ZnAl_2O_4$, *ibid.* 18B, 29. **166.** New Methods and Viewpoints in the Synthesis of Minerals and Rocks, *Naturwiss.* 20, 337.

167. Goldschmidt, V. M. and Hauptmann, H. Isomorphism of Borates and Carbonates, *Nachr. Ges. Wiss. Göttingen, Math.-phys. Kl.* 1932, 53.

168. Goldsztaub, S. Crystalline Structure of Goethite, *Compt. rend.* 195, 964.

169. Goss, N. P. Comparative Study of Low-carbon Bessemer and Basic Openhearth Wires by X-ray Diffraction Methods, *Trans. Am. Soc. Steel Treating* 20, 314.

170. Goss, N. P. and Clark, G. L. X-ray Studies of Steel Wires of Medium Carbon Content, *Trans. Am. Soc. Steel Treating* 20, 471.

171. Gossner, B. and Fell, E. Sulfates of the Voltaite Type, *Ber.* 65B, 393.

172. Gossner, B. and Reichel, Ch. The Crystal Structure of a So-called Orthosilicate, *Centr. Mineral. Geol.* 1932A, 225.

173. Gossner, B. and Reindl, E. The Chemical Composition of Cordierite and Pollucite, *Centr. Mineral. Geol.* 1932A, 330.

174. Gossner, B. and Strunz, H. The Chemical Composition of Narsarsukite, *Z. Krist.* 82, 150. **175.** The Structural Relationship between Phosphates (Triphylite) and Silicates (Olivine) and the Chemical Composition of Ardennite, *ibid.* 83, 415.

176. Gottfried, C. The Space Group of Afwillite, *Z. Krist.* 84, 172.

177. Gottfried, C. and Schusterius, C. The Structures of the Perchlorates of Potassium and Ammonium, *Z. Krist.* 84, 65.

178. Graf, L. Corrosion Structure, Corrosion Mechanism and the Tamman Resistance Limits. X-ray Examination of Gold-Copper Single Crystals, *Metallwirtschaft* 11, 77, 91.

179. Greig, J. W. The Existence of the High-temperature Form of Cristobalite at Room Temperature and the Crystallinity of Opal, *J. Am. Chem. Soc.* 54, 2846.

180. v. d. Grinten, W. The Use of Monochromatic Radiation for X-ray Scattering in Gases, *Physikal. Z.* 33, 769.

181. Gruner, J. W. A New Method of Building Crystal Structure Models, *Am. Mineral.* 17, 35. **182.** Magnesiosussexite, a New Mineral from a Michigan Iron Mine, Isomorphous with Sussexite and Camsellite, *ibid.* 17, 509. **183.** The Crystal Structure of Kaolinite, *Z. Krist.* 83, 75. **184.** The Crystal Structure of Dickite, *ibid.* 83, 394.

185. Hägg, G. The Density and Crystal Structure of Magnesium Nitride, Mg_3N_2, *Z. Krist.* 82, 471. **186.** The Crystal Structure of Potassium and Rubidium Dithionates, *ibid.* 83, 265. **187.** The Crystal Structure of Cesium Dithionate, *Z. physik. Chem.* 18B, 327.

188. Halla, F. Structure Determination by Means of Weissenberg Photographs, *Z. Krist.* 82, 316.

189. Halla, F. and Mehl, E. The Space Lattice of Natrolite, *Z. Krist,* 83, 140.

190. Halla, F. and Zimmermann, L. The Structure of Lead Formate, *Z. Krist.* 83, 497.

191. Halmöy, E. and Hassel, O. X-ray Analysis of Crystals of 1,4-Diiodocyclohexane (m.p. 142° C) and 1,4-Dibromocyclohexane (m.p. 111° C), *Z. physik, Chem.* 16B, 234. **192.** X-ray Analysis of Crystals of the 1,4-Cyclohexandiol with the m.p. 139° C. (trans-Quinitol), *ibid.* 17B, 258.

Year 1932

193. Harper, W. R. Factors in the Design of Hot-cathode X-ray Tubes for Steady Running, *Proc. Cambridge Phil. Soc.* **28,** 497.

194. Hassel, O. and Kringstad, H. Crystal Structure of the Tetrahalides of the Lighter Elements II, *Z. physik Chem.* **15B,** 274. **195.** Size Relations of Some Complex Anions and Lattice Dimensions of Werner Coordination Compounds of the Fluorite or Yttrium Fluoride Type, *Z. anorg. Chem.* **209,** 281.

196. Hassel, O. and Luzanski, N. X-ray Investigation of Ammonium Bifluoride, *Z. Krist.* **83,** 448.

197. Hatsuta, K. Equilibrium Diagram of the Chromium-Carbon System, *Tech. Repts. Tôhoku Imp. Univ.* **10,** 186.

198. Hauptmann, H. and Novák, J. Lattice Constants of Certain Substances of the Spinel Type, *Z. physik. Chem.* **15B,** 365.

199. Heide, F., Herschkowitsch, E. and Preuss, E. A New Hexahedrite from Cerros del Buen Huerto, Chile, *Chem. Erde* **7,** 483.

200. Heike, W., Schramm, J. and Vaupel, O. The Structure of Nickel-Zinc Alloys I, *Metallwirtschaft* **11,** 525, 539.

201. Helwig, G. V. The Structure of Potassium Dithionate and the Measurement of the Integrated Reflection from a Small Crystal, *Z. Krist.* **83,** 485.

202. Hendricks, S. B. p-Bromochlorobenzene and its Congeners: Various Equivalent Points in Molecular Lattices, *Z. Krist.* **84,** 85. **202a.** Lustrous Carbon, a Different Form? *ibid.* **83,** 503.

203. Hendricks, S. B., Jefferson, M. E. and Mosley, V. M. The Crystal Structures of Some Natural and Synthetic Apatite-like Substances, *Z. Krist.* **81,** 352.

204. Hendricks, S. B., Posnjak, E. and Kracek, F. C. Molecular Rotation in the Solid State. The Variation of the Crystal Structure of Ammonium Nitrate with Temperature, *J. Am. Chem. Soc.* **54,** 2766.

205. Hengstenberg, J. and Garrido, J. Electron Distribution in Carborundum, *Anales soc. españ. fis. quim.* **30,** 409.

206. Hengstenberg, J. and Mark, H. The Significance of X-ray Structural Analysis in Organic Chemistry, *Naturwiss.* **20,** 539.

207. Hengstenberg, J. and Palacios, J. The Structure of Dianthracene, *Anales soc. españ. fis. quim.* **30,** 5.

208. Hergenrother, R. C. A Precision Method of Measuring Small Changes of Lattice Spacing of Metal Single Crystals, *Physics* **2,** 63.

209. Hermann, C. and Ruhemann, M. The Crystal Structure of Mercury, *Z. Krist.* **83,** 136.

210. Herrmann, K. and Krummacher, A. H. X-ray Investigation of Liquid Crystalline Substances, *Z. Krist.* **81,** 317.

211. Hertel, E. and Römer, G. H. X-ray Investigation of a Case of Chromoisomerism, *Z. physik. Chem.* **19B,** 228.

212. Hertel, E. and Schneider, K. X-ray Investigation of Color Dimorphism among Stilbene Derivatives, *Z. physik. Chem.* **18B,** 436.

213. Hess, K. Old and New Viewpoints as to the Structure of Cellulose and their Experimental Bases, *Uspekhi Khim.* (*Progress Chem. U.S.S.R.*) **1,** 669.

214. Hess, K., Garthe, E. and Trogus, C. Melting Methylcellulose, *Cellulosechemie* **13,** 156.

215. Hess, K. and Klages, F. Acetolysis of Cellulose V. Water-soluble Dextrins from Cellulose, *Ann. Chem.* (*Liebig's*) **497,** 234.

216. Hey, M. H. and Bannister, F. A. Studies on the Zeolites II. Thomsonite (Including Faroelite) and Gonnardite, *Mineralog. Mag.* **23,** 51. **217.** III. Natrolite and Metanatrolite, *ibid.* **23,** 243.

218. Hilpert, S., Wille, A. and Lindner, A. Connection between Ferromagnetism and Structure of Ferrites, *Z. physik. Chem.* **18B,** 291.

219. Hofmann, W. Structural and Morphological Relations between Ores of the Formula Type ABC_2, *Fortschr. Min. Krist. Pet.* **17,** 422. **220.** Supplement to my Work: the Structure of Tutton's Salts, *Z. Krist.* **82,** 323.

221. Hofmann, U. and Lemcke, W. Crystal Structure and Catalytic Activity of Carbon, *Z. anorg. Chem.* **208,** 194.

222. Hofmann, U. and Wilm, D. X-ray Determination of Size and Form of Crystals of Carbon, *Z. physik. Chem.* **18B,** 401.

223. Holgersson, S. A New Synthesis of Copper Aluminate, *Z. anorg. Chem.* **204,** 378. **224.** Synthesis and X-ray Investigation of Nickel Chromite, *ibid.* **204,** 382.

225. Honda, K. and Nishiyama, Z. The Nature of the Tetragonal and Cubic

Martensites, *Trans. Am. Soc. Steel Treating* **20,** 464; *Sci. Repts. Tôhoku Imp. Univ.* **21,** 299.

226. **Huggins, M. L.** Some Significant Results of Crystal Structure Analysis, *Chem. Rev.* **10,** 427.

227. **Hund, F.** Theory of High-melting Non-conducting Atomic Lattices, *Z. Physik* **74,** 1.

228. **Huppertsberg, A.** Absolute Measurement of X-rays with the Help of the Electron Counter, *Z. Physik* **75,** 231.

229. **Isaichev, I. and Kurdyumov, G.** The Eutectic Decomposition of Tin Bronzes, *Metallwirtschaft* **11,** 554.

230. **Ishizawa, M.** Nitridation of Nitralloy, *Suiyokaishi* **7,** 165.

231. **Ito, T. and West, J.** The Structure of Hemimorphite, *Z. Krist.* **83,** 1. 232. The Structure of Bertrandite, *ibid.* **83,** 384.

233. **Iwasê, K. and Fukusima, M.** Experiments with Perovskite and Titanite, *Bull. Chem. Soc. Japan* **7,** 91; *Sci. Repts. Tôhoku Imp. Univ.* **21,** 114.

234. **Iwasê, K. and Nasu, N.** X-ray Study on the Electrolytic Iron-Nickel Alloys, *Bull. Chem. Soc. Japan* **7,** 305.

235. **Jaeger, F. M. and Beintema, J.** The Structure of Tetra- and Triphosphonitrile Chloride, *Proc. Acad. Sci. Amsterdam* **35,** 756.

236. **Jaeger, F. M. and Bottema, J. A.** The Exact Measurement of the Specific Heats of Solid Substances at High Temperatures VI. The Law of Neumann-Joule-Kopp-Regnault Concerning the Molecular Heat of Chemical Compounds as a Function of the Atomic Heats, *Proc. Acad. Sci. Amsterdam* **35,** 352.

237. **Jaeger, F. M. and Rosenbohm, E.** The Exact Measurement of the Specific Heats of Solid Substances at High Temperatures XI. On the Remarkable Behavior of Beryllium after Preliminary Heating above 420° C, *Proc. Acad. Sci. Amsterdam* **35,** 1055.

238. **Jaeger, F. M. and Zanstra, J. E.** The Structure of the Ammonium, Rubidium and Thallium Osmiamates, *Proc. Acad. Sci. Amsterdam* **35,** 787. 239. The Structure of Cesium Osmiamate, *ibid.* **35,** 779. 240. The Structure of Potassium Osmiamate, *ibid.* **35,** 610. 241. The Structure of the Alkali Osmiamates, *Rec. trav. chim.* **51,** 1013.

242. **Jänecke, E. and Brill, R.** The Existence of Tricalcium Silicate, *Zement* **21,** 380.

243. **James, R. W.** The Effect of Temperature upon the Scattering of X-rays by Gas Molecules, *Physikal. Z.* **33,** 737.

244. **Jauncey, G. E. M. and Williams, P. S.** Diffuse Scattering of X-rays from Sodium Fluoride, *Phys. Rev.* **41,** 127.

245. **Jensen, H.** Charge Distribution in Ions and Lattice Constant of Rubidium Bromide by the Statistical Method, *Z. Physik* **77,** 722.

246. **Jette, E. R. and Foote, F.** Solid Solutions of Lead and Tin in Bismuth, *Phys. Rev.* **39,** 1018.

247. **Jimenez, I. N.** Crystalline Structure of Barium Tungstate, *Rev. acad. cienc. Madrid* **29,** 111.

248. **de Jong, W. F.** The X-ray Laboratory, *Lustrum Yearbook of the Min. Eng. Soc. Delft* **1931-32.** 249. Different Forms of the Gutta-percha Hydrocarbon, *Rec. trav. chim.* **51,** 61. 250. The Crystal Structure of the Cubic Na-W-Bronzes, *Z. Krist.* **81,** 314.

251. **de Jong, W. F. and Stek, H. J.** Blue Na-W-Bronze, *Z. Krist.* **83,** 496.

252. **Jung, H.** Thuringite and Chamosite, *Chem. Erde* **7,** 594.

253. **Juza, R. and Biltz, W.** The Systematic Doctrine of Affinity LVII. The Phase Diagram of Pyrite, Pyrrhotite, Troilite and Sulfur Vapor, Criticized in View of Sulfur Vapor Pressures, X-ray Diagrams, Densities and Magnetic Measurements, *Z. anorg. Chem.* **205,** 273.

254. **Katz, J. R.** Polymorphism in Substances of High Molecular Weight III. The Relationship between the Mutarotation and X-ray Spectrum of Gelatin during Gelation, *Rec. trav. chim.* **51,** 835.

255. **Katz, J. R. and Derksen, J. C.** Changes in the X-ray Spectrum during Swelling of Gelatin and of Agar. Binding of Water within the Micelles of Swelling Substances, *Rec. trav. chim.* **51,** 513. 256. Physical Chemistry of Starch and Bread Making IX. The X-ray Spectrum of α-Diamylose Closely Corresponds with that of Certain Starch Preparations, *Z. physik. Chem.* **158A,** 337.

Year 1932

257. **Katz, J. R. and Weidinger, A.** Polymorphism in Substances of High Molecular Weight IV. An Attempt to Explain the Isomerism of Polysaccharides (Cellulose, Starch), *Rec. trav. chim.* 51, 842. 258. De-swelling as a Cause of the Characteristic Lack of Sharpness of Acetylcellulose I, *ibid.* 51, 847.

259. **Keen, R. C.** Survey of Analysis of Crystals by X-rays, *Proc. Louisiana Acad. Sci.* 1, 14.

260. **Kersten, H.** A Gas X-ray Tube for Crystal Structure Analysis, *Rev. Sci. Instruments* 3, 145. 261. An X-ray Reflection Spectrograph, *ibid.* 3, 384. 262. Influence of Hydrogen Ion Concentration on the Crystal Structure of Electrodeposited Cobalt, *Physics* 2, 274. 263. Influence of Temperature on the Crystal Structure of Electrodeposited Antimony, *ibid.* 2, 276. 264. Examination of Electrodeposited Metals and Alloys with X-rays, *Ind. Eng. Chem., Anal. Ed.* 4, 178.

265. **Kersten, H. and Lange, W.** An Improved Laue Camera, *Rev. Sci. Instruments* 3, 493. 266. A Method for Preparing Crystals for Rotation Photographs, *ibid.* 3, 790.

267. **Kersten, H. and Maas, J.** The Crystal Structure of Black Nickel, *Physics* 3, 137. 268. Electrodeposited ϵ-Brass, *J. Phys. Chem.* 36, 2175.

269. **Ketelaar, J. A. A.** The Crystal Structure of PbF_2, *Z. Krist.* 84, 62.

270. **Khouvine, Y.** X-ray Study of Chitin from *Aspergillus niger, Psalliota campestris* and *Armillaria mellea, Compt. rend.* 195, 396.

271. **Khouvine, Y., Champetier, G. and Sutra, R.** X-ray Study of the Cellulose of *Acetobacter xylinus, Compt. rend.* 194, 208.

272. **Kolkmeijer, N. H. and Moesveld, A. L. Th.** Regler's Standard Method for the Accurate Determination of Lattice Dimensions and that of the Authors, *Physikal. Z.* 33, 265.

273. **Komar, A. P.** Application of X-rays to the Study of Elastic Strain in Crystalline Substances, *J. Tech. Phys.* (*U.S.S.R.*) 2, 519.

274. **Konobejewski, S. and Mirer, I.** X-ray Determination of Elastic Tension in Bent Crystals, *Z. Krist.* 81, 69.

275. **Kôzu, S.** Studies of Cancrinite from Korea, *Jap. J. Geol.* 9, *Abstr.* 1-2; *Mineralog. Abstr.* 5, 48.

276. **Krasnikov, A. I.** A Method for Obtaining Debye-Scherrer X-ray Photographs of Greatest Accuracy, *J. Exptl. Theoret. Phys.* (*U.S.S.R.*) 2, 74.

277. **Kratky, O.** Convergent X-rays as a Means of Producing Layer Line Diagrams in a Shorter Time, *Z. Krist.* 82, 152.

278. **Kratky, O. and Eckling, K.** Examination of Microscopic Crystals with X-rays III. Micro X-ray Goniometer, *Z. physik. Chem.* 19B, 278.

279. **Krause, A., Czapska, Z. and Stock, J.** Silver Ferrites IV. Determination of the Structure of Ferric Hydroxides with the Aid of the Silver Ferrite Synthesis, *Z. anorg. Chem.* 204, 385.

280. **Ksanda, C. J.** A Metal X-ray Tube for Characteristic Radiation, *Rev. Sci. Instruments* 3, 531.

281. **Kurdyumov, G.** The Heat Treating of Carbon Steels in the Light of X-ray Investigations, *Arch. Eisenhüttenw.* 6, 117.

282. **Laves, F.** Crystal Structure of Gallium, *Naturwiss.* 20, 472.

283. **Lenel, F. V.** The Structures of Some Simple Glycine Polypeptides, *Z. Krist.* 81, 224.

284. **Laves, F.** Classification of the Silicates. Geometric Investigations of Possible Silicon-Oxygen Bonds as a Possible Way of Joining Regular Tetrahedra, *Z. Krist.* 82, 1. 285. Relation between Coordination Numbers and Valence Electrons in Intermetallic Compounds, *Nachr. Ges. Wiss. Göttingen, Math.-phys. Kl.* 1932, 519.

286. **Lengyel, B.** X-ray Investigation of the Function of the Crystal Water in Zeolites, *Z. Physik* 77, 133.

287. **Levi, G. R. and Ghiron, D.** The Structural Formula of Hydromagnesite, *Gazz. chim. ital.* 62, 218.

288. **Levin, I. and Ott, E.** The Crystallinity of Opals and the Existence of High Temperature Cristobalite at Room Temperature, *J. Am. Chem. Soc.* 54, 828. 289. Observations Concerning the Structure of Interference Lines Obtained by the Powder Method, *Z. Krist.* 84, 167.

290. **Lihl, F.** Precision Measurements of the Lattice Constant of Arsenic Trioxide, *Z. Krist.* 81, 142. 291. The Influence of Divergence, Sample Thickness and

Year 1932

Depth of Penetration on Precision Measurements of Lattice Dimensions by the Debye-Scherrer Method, *ibid.* 83, 193.

292. **Linde, J. O.** The Lattice Constants of Copper-Palladium Mixed Crystals, *Ann. Physik* 15, 249.

293. **McCrea, G. W.** An X-ray Examination of d-Mannitol and d-Mannose, *Proc. Roy. Soc. Edinburgh* 51, 190.

294. **Machatschki, F.** The Formula of Vesuvianite, *Z. Krist.* 81, 148. 295. The Magnesium-Gallium Spinel, *ibid.* 82, 348. 296. The Crystal Structure of Pyrrhite, *Centr. Mineral. Geol.* 1932A, 33. 297. Crystal Chemistry of the Silicates, *Geol. Fören. Förh.* 54, 447.

298. **Machatschki, F. and Zedlitz, O.** The Crystal Structure of Lewisite, *Z. Krist.* 82, 72.

299. **Mark, H. and v. Susich, G.** Lattice Distortions and the X-ray Detection of Inner Strains, *Z. Ver. deut. Ing.* 76, 1049.

300. **Marwick, T. C.** An X-ray Study of Mannitol, Dulcitol and Mannose, *Nature* 130, 96.

301. **Matano, C.** X-ray Studies of the Diffusion of Copper into Nickel, *Mem. Coll. Sci. Kyoto Imp. Univ.* 15A, 351.

302. **Mathewson, C. H., Spire, E. and Samans, C. H.** Division of the Iron-Vanadium-Oxygen System into Some of its Constituent Binary and Ternary Systems, *Trans. Am. Soc. Steel Treating* 20, 357.

303. **Mayer, F. K.** The Modifications of Calcium Carbonate in the Shells and Skeletons of Organisms, *Chem. Erde* 7, 346.

304. **Mayer, J. E. and Helmholz, L.** The Lattice Energy of the Alkali Halides and the Electron Affinity of the Halogens, *Z. Physik* 75, 19.

305. **Mayer, J. E. and Maltbie, M. McC.** The Lattice Energies of the Alkaline Earth Oxides and Sulfides and the Electron Affinities of Oxygen and Sulfur, *Z. Physik* 75, 748.

306. **Megaw, H. D.** Lattice Dimensions in Copper-Silver Alloys, *Phil. Mag.* 14, 130.

307. **Mehmel, M.** Crystal Structure of Boracite, *Fortschr. Min. Krist. Pet.* 17, 436.

308. **Meisel, K.** Rhenium Trioxide III. The Crystal Structure of Rhenium Trioxide, *Z. anorg. Chem.* 207, 121.

309. **Menke, H.** X-ray Interference by Liquids (Mercury, Gallium, Carbon Tetrachloride), *Physikal. Z.* 33, 593.

310. **Menzer, G.** Precise Estimation of Lattice Constants by Means of the Powder Methods, *Fortschr. Min. Krist. Pet.* 16, 1290. 311. The Crystal Structures of the Cryolite Group, *ibid.* 17, 439.

312. **Merritt, P. L.** The Identification of Jade by Means of X-ray Diffraction Patterns, *Am. Mineral.* 17, 497.

313. **Meyer, H.** Note on the Work: Improvement of Zinc-Aluminum Alloy, Al_2Zn_3, *Z. Physik* 78, 854.

314. **Miles, F. D.** Methods and Results of the X-ray Investigation of Subcrystalline Materials, *J. Soc. Chem. Ind.* 51, *Trans. Commun.* 247.

315. **Miller, W. S., Chesley, K. G., Anderson, H. V. and Theis, E. R.** X-ray Study of the Coagulation of Egg Albumin, *J. Am. Leather Chem. Assoc.* 27, 174.

316. **Mooy, H. H.** Preliminary Experiments with X-rays on Oxygen, Acetylene and Ethylene in the Solid State, *Rappts. Commun.* No. 24, *Cong. inter. froid Buenos Aires, Commun. Kamerlingh Onnes Lab. Univ. Leiden* No. 223, 1.

317. **Morell, L. G. and Hanawalt, J. D.** X-ray Study of the Plastic Working of Magnesium Alloys, *Physics* 3, 161.

318. **Motzok, D. K.** Open Polytopes, *Trans. Russian Min. Soc.* 61, 140.

319. **Müller, A.** Rotation of Chain Molecules in Solid Paraffins, *Nature* 129, 436. 320. X-ray Investigation of Normal Paraffins near their Melting Points, *Proc. Roy. Soc.* (*London*) 138A, 514.

321. **Nahmias, M. E.** Quantitative Crystal Analysis by Means of X-rays, *Z. Krist.* 83, 329.

322. **Natta, G.** Structure of Hydroxides and Hydrates IV. Octahydrated Strontium Peroxide, *Gazz. chim. ital.* 62, 444; *Atti III cong. naz. chim. pura appl.* 1929, 347.

323. **Natta, G. and Baccaredda, M.** The So-called Ocher of Antimony, *Atti IV cong. naz. chim. pura appl.* 1932, 1. 324. Calcium Antimonate Ores (Atopite, Romeite, Calcium Antimony Ocher), *Rendiconti accad. Lincei* 15, 389.

325. **Natta, G. and Pirani, R.** Solid Solutions by Precipitation and Isomorphism

of Complexes of Quadrivalent Platinum and Tellurium I. The Structures of the Chloroplatinates of Cesium and Rubidium, *Rendiconti accad. Lincei* 15, 92. 326. II. The Chlorotellurite of Cesium and the Systems: Cs_2PtCl_6-Cs_2TeCl_6, Rb_2PtCl_6-Cs_2PtCl_6, *ibid.* 16, 265.

327. **Neskuchaev, V.** The Structure Factor, *J. Exptl. Theoret. Phys.* (*U.S.S.R.*) 2, 171.

328. **Neuburger, M. C.** Precision Measurements of Lattice Constants by the Powder Method, *Z. Elektrochem.* 38, 631. 329. Precision Determination of Lattice Constants of Beryllium, *Z. physik. Chem.* 17B, 285.

330. **Nieuwenkamp, W. and Bijvoet, J. M.** The Crystal Structure of Lead Fluochloride, *Z. Krist.* 81, 469. 331. The Crystal Structure of Lead Fluobromide, *ibid.* 82, 157. 332. The Crystal Structure of Lead Bromide, *ibid.* 84, 49.

333. **Niggli, P.** Method of Notation for the Constants of the Lattice Types A_nB_m, *Z. Krist.* 83, 111. 334. The Mineral Chemistry of Volcanic Rock and Pegmatite, *Schweiz. Mineralog.-Petrograph. Mitt.* 12, 204.

335. **Niggli, P. and Brandenberger, E.** Stereochemistry of Crystal Compounds VII. SiO_2 Structures and Structure Principles of the Chief Rock-forming Silicates, *Z. Krist.* 82, 210.

336. **Nishiyama, Z.** On the Corrections for Debye-Scherrer X-ray Photographs, *Sci. Repts. Tôhoku Imp. Univ.* 21, 364.

337. **Noll, F. H. W.** X-ray Diffraction in Ethyl Ether near the Critical Point, *Phys. Rev.* 42, 336.

338. **Novák, J.** Cristobalite from Serpentines of West Moravia, *Publ. Faculty Sci. Univ. Masaryk, Brno* 1932, No. 155.

339. **Nowacki, W.** Stereochemistry of Crystal Compounds VIII. Geometric Derivation of Structure Types AB_3, *Z. Krist.* 82, 355. 340. IX. Geometric Derivation of Structure Types A_2B_3, *ibid.* 83, 97.

341. **Ölander, A.** The Crystal Structure of AuCd, *Z. Krist.* 83, 145.

342. **Oftedal, I.** The Crystal Structure of Covellite, *Z. Krist.* 83, 9. 343. The Space Group of Bournonite, *ibid.* 83, 157.

344. **Ohara, K. and Matsunaga, Y.** The Submicroscopic Structure of Silk II. X-ray Investigation of Dichroism of Silk, *Bull. Inst. Phys. Chem. Research* (*Tokyo*) 11, 769.

345. **Okamura, T.** On the Transformation of Magnetite at a Low Temperature, *Sci. Repts. Tôhoku Imp. Univ.* 21, 231.

346. **Onorato, E.** Symmetry and Structure of Hauerite, *Per. mineral.* 1, 109 (1930); *Neues Jahrb. Mineral. Geol. Referate I*, 1932, 26. 346a. The Hemihydrate of Calcium Sulfate and Soluble Anhydrite, *Per. mineral.* 3, 135; *Neues Jahrb. Mineral. Geol. Referate I*, 1932, 505.

347. **Orowan, E.** Remark on the Papers by F. Zwicky on the Structure of Real Crystals, *Z. Physik* 79, 573.

348. **Owen, E. A. and Iball, J.** Precision Measurements of the Crystal Parameters of Some of the Elements, *Phil. Mag.* 13, 1020.

349. **Owen, E. A. and Pickup, L.** Interdiffusion of Metals, *Nature* 130, 201. 350. X-ray Study of Phase Boundaries in Thermal Diagrams of Alloy Systems: Cu-Zn System, *Proc. Roy. Soc.* (*London*) 137A, 397.

351. **Palache, C. and Foshag, W. F.** The Chemical Nature of Joaquinite, *Am. Mineral.* 17, 308.

352. **Parker, H. M. and Whitehouse, W. J.** X-ray Analysis of Iron Pyrites by the Method of Fourier Series, *Phil. Mag.* 14, 939.

353. **Parravano, N. and Caglioti, V.** Structure and Chemical Composition of Some [Manganese-Zinc and Cobalt-Zinc] Alloys, *Mem. accad. Italia, Cl. sci. fis. mat. nat.* 3, *Chim.* No. 3, 5.

354. **Passerini, L.** Quantitative Relations between Solubility in the Solid State and Atomic Dimensions for Oxides of Bivalent, Tervalent and Quadrivalent Metals, *Gazz. chim. ital.* 62, 85.

355. **Passerini, L. and Pirani, R.** Structure of Complex Salts Containing Coordinated Atoms or Groups of Different Kinds I. Complexes with a Coordination Number of 6. The Salts $(NH_4)_3[VF_6]$ and $Tl_2[VF_5(H_2O)]$, *Gazz. chim. ital.* 62, 279. 356. II. Complexes with a Coordination Number of 6. The Salts $(NH_4)_3[CrF_6]$ and $Rb_2[CrF_5(H_2O)]$, *ibid.* 62, 289.

357. **Pauling, L.** Interatomic Distances in Covalent Molecules and Resonance

between Two or More Lewis Electronic Structures, *Proc. Natl. Acad. Sci.* 18, 293. 358. The Packing of Spheres, *Chem. Bull.* 19, 35.

359. **Pauling, L. and Brockway, L. O.** The Crystal Structure of Chalcopyrite, *Z. Krist,* 82, 188.

360. **Pauling, L. and Sherman, J.** Screening Constants for Many-electron Atoms. The Calculation and Interpretation of X-ray Term Values and the Calculation of Atomic Scattering Factors, *Z. Krist.* 81, 1.

361. **Perlitz, H.** On Variations of Interatomic Distances with the Change from the Cubic Face-centered Arrangement to the Cubic Body-centered or to the Hexagonal Close-packed Arrangement, *Trans. Faraday Soc.* 28, 514. 362. The Principles of Electron Valence Concentration in Binary Intermetallic Alloys, *Acta Commentationes Univ. Tartu* XXIVA.

363. **Perret, A. and Gislon, A.** A Supposed Sodium Isonitriloferrocyanide, *Bull. soc. chim. France* 51, 480.

364. **Phelps, R. T. and Davey, W. P.** An X-ray Study of the Nature of Solid Solutions, *Am. Inst. Min. Met. Eng., Inst. Metals Div., Tech. Pub.* No. 443.

365. **Pickup, L.** The Trend of X-ray Analysis in Metallurgy, *Metallurgia* 5, 177.

366. **Pirie, N. W. and Bernal, J. D.** Cuprous Glutathione, *Biochem. J.* 26, 75.

367. **Powell, H. M. and Crowfoot, D. M.** Layer-chain Structures of Thallium Dialkyl Halides, *Nature* 130, 131.

368. **Prasad, M. and Desai, K. V.** An X-ray Examination of the Crystals of o-Azotoluene, *Phil. Mag.* 13, 600.

369. **Preston, G. D.** An X-ray Examination of Iron-Chromium Alloys, *Phil. Mag.* 13, 419.

370. **Quill, L. L.** The Crystal Structure of Yttrium, *Z. anorg. Chem.* 208, 59. 371. The Lattice Constants of Columbium, Tantalum and Several Columbates and Tantalates, *ibid.* 208, 257. 372. X-ray Investigation of Metallic Lanthanum, Cerium and Neodymium, *ibid.* 208, 273.

373. **Quittner, F., Sapgir, J. and Rassudowa, N.** Rhombic Modification of Lead Chromate, *Z. anorg. Chem.* 204, 315.

374. **Ramsdell, L. S.** An X-ray Study of Psilomelane and Wad, *Am. Mineral.* 17, 143.

375. **Randall, J. T. and Rooksby, H. P.** Polish on Metals, *Nature* 129, 280. 376. Diffraction of X-rays by Liquid Metals, *ibid.* 130, 473.

377. **Regler, F.** A New Method for the X-ray Investigation of the Processes of Elastic and Plastic Deformation of Polycrystalline Metals, *Physikal. Z.* 33, 435. 378. A New Method for a Complete X-ray Investigation of the Fine Structure of Technical Metals, *Z. Physik* 74, 547.

379. **Reinicke, R.** Structural Relationships of Silicon Compounds on the Basis of Tetrahedral Domains of Atoms, *Z. Krist.* 82, 394. 380. Geometric Derivation of Cubic Structures as an Aid in Structure Determination, *ibid.* 82, 419. 381. Tetrahedral Representation of the Carbonate and Nitrate Groups, *ibid.* 84, 159.

382. **Richter, H.** The Scattering of X-rays by Chlorine, *Physikal. Z.* 33, 587.

383. **Ringdal, H. T.** Mixed Crystals of Alkaline Earth Nitrates, *Z. Krist.* 82, 50.

384. **Rinne, F.** The Relation of Hydrated Bromophenanthrene Sulfonic Acid to Organic Paracrystals, *Z. Krist.* 82, 379. 385. Paracrystalline and Crystalline N-Anisal-4-Phenylazo-1-Naphthylamine, *ibid.* 83, 227. 386. Remarks on the Existence of Paracrystals and their Share in Cerebrosides and Phosphatides as Constituents of Plasma, *Kolloid-Z.* 60, 288.

387. **Rodolico, F.** Water Content of Tremolite of Monte Spinoza, Campiglia, *Rendiconti accad. Lincei* 16, 645. 388. The Supposed Wurtzite of Spannochia and Accesa, Tuscany, *Per. mineral.* 1, 167 (1930); *Neues Jahrb. Mineral. Geol. Referate I,* 1932, 334.

389. **Rooksby, H. P.** Color of Selenium Ruby Glasses, *J. Soc. Glass Tech.* 16, 171.

390. **Rossi, A.** The Crystalline Structure of Praseodymium, *Rendiconti accad. Lincei* 15, 298.

391. **Ruhemann, M.** X-ray Investigation of Solid Nitrogen and Oxygen, *Z. Physik* 76, 368.

392. **Ruhemann, B. and Simon, F.** Crystal Structures of Krypton, Xenon, Hydrogen Iodide and Hydrogen Bromide in Relation to the Temperature, *Z. physik. Chem.* 15B, 389.

393. **Sakurada, I. and Hutino, K.** X-ray Investigation of Cellulose Xanthate, ***Sci. Pap. Inst. Phys. Chem. Research* (*Tokyo*) 17, 294.**

Year 1932

394. **Salvia, R.** X-ray Study of the Structure of Stephanite, *Anales soc. españ. fis. quim.* 30, 416.

395. **Samec, M., Katz, J. R. and Derksen, J. C.** Physical Chemistry of Starch and Bread Making VIII. To what Extent do Substances Related to Native Starch Undergo Gelatinization and Retrogradation? *Z. physik. Chem.* 158A, 321.

396. **Sauter, E.** The Rotation Goniometer Diagram and the Reciprocal Lattice, *Naturwiss.* 20, 889. 397. Highly Polymerized Compounds LXXI. X-ray Examination of Polyoxymethylenes of High Molecular Weight, *Z. physik. Chem.* 18B, 417. 398. X-ray Investigation of Polymeric and Monomeric Butadiene Sulfones, *Z. Krist.* 83, 340.

399. **Scheil, E. and Schulz, E. H.** Heat-resistant Chromium-Aluminum Steels, *Arch. Eisenhüttenw.* 6, 155.

400. **Schiebold, E.** Investigation of Biological Structures by Means of X-rays, *Verhandl. deut. Röntgen-Ges.* 24, 1. 401. Crystal Structure of Silicates, *Ergebnisse exakt. Naturwiss.* 11, 352.

402. **Schiebold, E. and Seumel, G.** The Crystal Structure of Scapolite, *Z. Krist.* 81, 110.

403. **Schleede, A., Schmidt, W. and Kindt, H.** Calcium Phosphates and Apatites, *Z. Elektrochem.* 38, 633.

404. **Schleede, A. and Wellmann, M.** Preparation of Lindemann Glass for X-ray Capillary Tubes for Photographing Substances Sensitive to Air with Long Wave Length X-rays, *Z. Krist.* 83, 148. 405. Structure of Products of Action of Alkali Metals on Graphite, *Z. physik. Chem.* 18B, 1.

406. **Schmid, E.** The Significance of X-ray Interferences for Metallography, *Naturwiss.* 20, 530.

407. **Schmid, E. and Seliger, H.** Investigation of the Binary Solid Solutions of Magnesium, *Metallwirtschaft* 11, 409, 421.

408. **Schmid, E. and Siebel, G.** Does the Change of Lattice Constants during the Formation of Solid Solutions Depend on Grain Size? *Metallwirtschaft* 11, 685.

409. **Schmid, E. and Wassermann, G.** Is there a Compound Al_2Zn_3? *Metallwirtschaft* 11, 386; *Mitt. deut. Materialprüfungsanstalt* 1932, 218. 410. X-ray Investigations of Electrolytically Oxidized Aluminum, *Hausztschr. V. A. W. Erstwerk A. G. Aluminium* 4, 100.

411. **Schnaasse, H.** The Crystal Structure of Red Manganese Sulfide, *Naturwiss.* 20, 640.

412. **Schneider, K.** Organic Molecular Compound with a Small Unit Cell, *Z. physik. Chem.* 16B, 460.

413. **Schwartz, H. A., Van Horn, K. R. and Junge, C. H.** Transformation in the Carbide Phase during Graphitization, *Pap. Presented at the 14th Ann. Conv. Am. Soc. Steel Treating, Oct.* 1932.

414. **v. Schwarz, M. and Summa, O.** New Determination of the Lattice Constant of Titanium Carbide, *Z. Elektrochem.* 38, 743. 415. Is there a Compound Al_2Zn_3? *Metallwirtschaft* 11, 369. 416. Practical Auxiliaries in the Evaluation of Atomic Structural Investigations, *Forschungsarb. Metallkunde Röntgenmetallographie* No. 6.

417. **Seemann, H.** A New X-ray Interference Method for Polycrystalline Substances, Especially those Having Cylindrical Symmetry or Fibrous Structure, *Physikal. Z.* 33, 755.

418. **Seifert, H.** The Crystal Structure of Double Salts with Unlike Anions, *Z. Krist.* 83, 274. 419. Investigation on Fluorine Compounds and on the Crystal Chemistry of Double Salts and "Anomalous Mixed Crystals," *Fortschr. Min. Krist. Pet.* 17, 1.

420. **Sherman, J.** Note on Dr. Wheeler's Discussion of the Madelung Constants for Some Cubic Crystal Lattices, *Phil. Mag.* 14, 745. 421. Crystal Energies of Ionic Compounds and Thermo-chemical Applications, *Chem. Rev.* 11, 93.

422. **Shinoda, G.** Eutectoid Transformation of Bronze, *Suiyokaishi* 7, 367.

423. **Shôji, H.** X-ray Investigation of the Change of Direction of Crystal Axes during an Allotropic Change of a Substance, *Bull. Inst. Phys. Chem. Research (Tokyo)* 11, 896. 424. X-ray Investigation of the Change in Orientation of the Crystal Lattice with Change in Modification of a Substance, *Z. Krist.* 84, 74.

425. **Sieg, L.** Crystal Structure of Ammonium Hexabromoselenate, *Z. anorg. Chem.* 207, 93.

Year 1932

426. **Smith, D. W.** A Study of Segregate Structures in Copper-Tin and Silver-Zinc Alloys, *Am. Inst. Min. Met. Eng., Buffalo Meeting Oct.* 1932.

427. **Solacolu, S.** Ternary Compound: $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$, *Zement* 21, 301.

428. **v. Stackelberg, M. and Neumann, F.** Crystal Structure of Borides of Composition MeB_6, *Z. physik. Chem.* 19B, 314.

428a. **Stenzel, W. and Weerts, J.** Precision Determination of Lattice Constants of Non-cubic Substances, *Z. Krist.* 84, 20.

429. **Stillwell, C. W. and Audrieth, L. F.** Glacial Acetic Acid as a Solvent for the Electrodeposition of Metals. An X-ray Diffraction Study of the Structure of Deposits of Arsenic, Antimony and Bismuth, *J. Am. Chem. Soc.* 54, 472.

430. **Stillwell, C. W. and Stout, L. E.** The Crystal Structures of Electrodeposited Alloys. An X-ray Diffraction Study of Silver-Cadmium Deposits, *J. Am. Chem. Soc.* 54, 2583.

431. **Stratta, R.** The Existence of a Mercury Chlorobromide, *Ind. chim.* 7, 726.

432. **Straumanis, M. and Weerts, J.** The Liberation of the α-Phase in β-Brass, *Z. Physik* 78, 1.

433. **Straumann, R.** Detection of the Crystal Structure of the Inorganic and Organic Bone Substances, *Helv. Phys. Acta* 5, 300.

434. **Swjaginzeff, O. E.** Osmiridium I. (with Brunowski, B. K.) II. X-ray Investigation, *Z. Krist.* 83, 172, 187.

435. **Sykes, W. P. and Van Horn, K. R.** The Intermediate Phases of the Iron-Tungsten System, *Am. Inst. Min. Met. Eng., Buffalo Meeting Oct.* 1932.

436. **Takanê, K.** Crystal Structure of Bronzite from Chichi-jima in the Bonin Islands, *Proc. Imp. Acad. Tokyo* 8, 308.

437. **Tani, Y.** Crystal Lattice Distribution in Stretched Aluminum, *J. Faculty Eng. Tokyo Imp. Univ.* 20, 133.

438. **Taylor, N. W.** Solid Cadmium Amalgams. An X-ray Proof of the Compound Cd_3Hg, *J. Am. Chem. Soc.* 54, 2713.

439. **Taylor, W. H.** Structure of Sillimanite and Related Materials, *J. Soc. Glass Tech.* 16, 111.

440. **Thibaud, J. and Dupré la Tour, F.** The Polymorphism of Saturated Long Chain Monobasic Acids. Influence of the Temperature, *J. chim. phys.* 29, 153.
441. Study of the Polymorphism of Fatty Acids as a Function of the Temperature, *J. phys. rad.* 3, 378.

442. **Thiessen, P. A. and Heumann, J.** A Comparison of the Intermetallic $AuCd_3$ Compounds Obtained by Fusion and from Solution, *Z. anorg. Chem.* 209, 325.

443. **Tokody, L.** Asterism of X-ray Photographs of Hessite, *Földtani Közlöny* 62, 1. 444. The Structure of Hessite, *Z. Krist.* 82, 154.

445. **Trillat, J. J.** Structure of Gelatin, *Ann. inst. Pasteur* 48, 400; *J. chim. phys.* 29, 1. 446. Structure Changes of Nitrocellulose Films during their Drying, *Compt. rend.*, 194, 1922.

447. **Trillat, J. J. and Forestier, H.** Some Physical Properties of Plastic Sulfur, *Bull. soc. chim. France* 51, 248.

448. **Trogus, C.** The X-ray Diagram of "Hendecamethyltriose" from Cellulose, *Naturwiss.* 20, 317.

449. **Tu, Y.** A Precision Comparison of Calculated and Observed Grating Constants of Crystals, *Phys. Rev.* 40, 662.

450. **Tutiya, H.** X-ray Observation of Molybdenum Carbides Formed at Low Temperatures, *Bull. Inst. Phys. Chem. Research* (*Tokyo*) 11, 1150.

451. **Umanskii, Y. and Gordon, E.** X-ray Investigation of Inner Strains in Hardened Cobalt Steels, *J. Tech. Phys.* (*U.S.S.R.*) 2, 323.

452. **Valouch, M. A.** The Structure of Rolled Zinc, *Metallwirtschaft* 11, 165.

453. **Vasiliev, K. V.** X-ray Tube with Demountable Filters, *Trans. Inst. Econ. Mineral. (U.S.S.R.)* No. 55, 3. 454. Multichamber X-ray Tube, *ibid.* No. 55, 7. 455. Universal Chamber for X-ray Photographs, *ibid.* No. 55, 20.

456. **Vegard, L.** Structure of β-Nitrogen and the Different Behavior of the Two Forms of Solid Nitrogen Regarding Phosphorescence, *Z. Physik* 79, 471.

457. **Wagner, G. and Dengel, G.** Crystal Structure and Molecular Configuration of Simple Derivatives of Tetramethylmethane I. Tetrachloro-, Tetrabromo- and Tetraiodohydrins of Pentaerythritol, *Z. physik. Chem.* 16B, 382.

458. **Waldmann, H. and Brandenberger, E.** Methylbixin, *Z. Krist.* 82, 77.

459. **Warren, B. E.** Structure of Asbestos. An X-ray Study, *Ind. Eng. Chem.* 24, 419.

Year 1932

460. **Wasastjerna, J. A.** On the Electron Distribution in Atoms and Ions, *Soc. Sci. Fennica Commentationes, Phys.-Math.* 6, No. 19. 461. The Wave Mechanical Significance of the Apparent Radii of Atoms and Ions, *ibid.* 6, No. 21. 462. The Forces between Atoms and Ions, *ibid.* 6, No. 22.

463. **Wassermann, G.** The Transformation of Cobalt, *Metallwirtschaft* 11, 61.

464. **Weerts, J.** Precision X-ray Methods in the Investigation of Alloys, *Z. Metallkunde* 24, 138. 465. The Transformation Process in β-Brass and in β-Silver-Zinc Alloys, *ibid.* 24, 265.

466. **Weiser, H. B. and Milligan, W. O.** The Transformation from Blue to Rose Cobaltous Hydroxide, *J. Phys. Chem.* 36, 722. 467. X-ray Studies on the Hydrous Oxides I. Alumina, *ibid.* 36, 3010. 468. II. Stannic Oxide, *ibid.* 36, 3030. 469. III. Stannous Oxide, *ibid.* 36, 3039.

470. **West, C. D.** The Crystal Structure of Rhombic Ammonium Nitrate, *J. Am. Chem. Soc.* 54, 2256.

471. **Westgren, A.** The Chemistry of Alloys, *Angew. Chem.* 45, 33. 472. Structural Analogies of Alloys, *Trans. Am. Soc. Steel Treating* 20, 507. 473. X-ray Investigations of the Constitution of Alloys, *Assoc. intern. essai matériaux, Cong. Zurich 1931,* I, 484. 474. Crystal Structure of Cementite, *Jernkontorets Ann.* 116, 457.

475. **Wever, F. and Jellinghaus, W.** The Influence of Chromium on the Transformations of Carbon Steels, *Mitt. Kaiser Wilhelm-Inst. Eisenforsch. Düsseldorf* 14, 105.

476. **Wheeler, T. S.** The Electrostatic Potential of Some Cubic Crystal Lattices, *Phil. Mag.* 14, 56.

477. **Wiest, P.** X-ray Investigation of the Solubility of Silver in Copper, *Z. Physik* 74, 225.

478. **Wollan, E. O.** X-ray Scattering and Atomic Structure, *Rev. Mod. Phys.* 4, 205.

479. **Woo, Y. H.** The Scattering of X-rays by Polyatomic Gases, *Phys. Rev.* 39, 555. (See also note on the above, Jauncey, G. E. M., *Phys. Rev.* 39, 561.). 480. The Scattering of X-rays by Gases and Crystals, *ibid.* 41, 21.

481. **Wooster, N.** The Crystal Structure of Ferric Chloride, *Z. Krist.* 83, 35.

482. **Wooster, W. A.** Crystal Structure and Dehydration Figures of Alkali Halide Hydrates, *Nature* 130, 698.

483. **Wrigge, F. W. and Meisel, K.** Molecular and Atomic Volumes XXXVI. The Density of Cuprous Oxide, *Z. anorg. Chem.* 203, 312.

484. **Wyckoff, R. W. G.** Some Single Crystal Spectrometric Data on Urea, *Z. Krist.* 81, 102.

485. **Wyckoff, R. W. G. and Corey, R. B.** The Crystal Structure of Thiourea, *Z. Krist.* 81, 386.

486. **Yamamoto, K.** Physico-chemical Properties of Japanese Acid Clay VI. X-ray Studies of Japanese Acid Clay, *J. Soc. Chem. Ind. Japan* 35, *Suppl. binding* 482.

487. **Zachariasen, W. H.** The Crystal Lattice of Potassium Pyrosulfite and the Structure of the Pyrosulfite Group, *Phys. Rev.* 40, 113. 488. Note on a Relation between the Atomic Arrangement in Certain Compounds, Groups and Molecules and the Number of Valence Electrons, *ibid.* 40, 914. 489. The Crystal Structure of Germano Sulfide, *ibid.* 40, 917. 490. The Crystal Lattice of Potassium Pyrosulfite and the Structure of the Pyrosulfite Group, *ibid.* 40, 923. 491. The Atomic Arrangement in Glass, *J. Am. Chem. Soc.* 54, 3841. 492. Note on the Crystal Structure of Silver Sulfate, *Z. Krist.* 82, 161.

493. **Zachariasen, W. H. and Ziegler, G. E.** The Crystal Structure of Anhydrous Sodium Sulfate, *Z. Krist.* 81, 92. 494. The Crystal Structure of Calcium Metaborate, *ibid.* 83, 354.

495. **Zambonini, F. and Laves, F.** The Crystal Structure of Lithium Phosphate and its Relation to the Olivine Type of Structure, *Z. Krist.* 83, 26.

496. **Zedlitz, O.** The Crystal Structure of Romeite and Schneebergite, *Z. Krist.* 81, 253.

497. **Zeidenfeld, S.** X-ray Micrograph for the Examination of Metallic Specimens, *J. Sci. Instruments* 9, 195. 498. Demountable Cell for the X-ray Investigation of Liquids, *ibid.* 9, 260.

499. **Zintl, E. and Dullenkopf, W.** Metals and Alloys III. Polyantimonides, Polybismuthides and their Transformation into Alloys, *Z. physik. Chem.* 16B, 183.

Year 1932

500. IV. Lattice Structure of Sodium Thallide and its Relation to Structures of the β-Brass Type, *ibid.* 16B, 195.

501. **Zintl, E. and Harder, A.** Metals and Alloys V. Lattice Structure of KBi$_3$, *Z. physik. Chem.* 16B, 206.

502. **Zwicky, F.** Secondary Structure and Mosaic Structure of Crystals, *Phys. Rev.* 40, 63.

503. **Parsons, A. L.** *Univ. Toronto Studies, Geol. Ser.* No. 14, p. 54.

Year 1933

1. **Adelsköld, V., Sundelin, A. and Westgren, A.** Carbides in Carbon-containing Alloys of Tungsten and Molybdenum with Chromium, Manganese, Iron, Cobalt and Nickel, *Z. anorg. Chem.* 212, 401.

2. **Ageev, N. and Shoiket, D.** Constitution of the Silver-rich Aluminum-Silver Alloys, *J. Inst. Metals* 52, 119.

3. **Aminoff, G.** (with an analysis by R. Blix). On the Structure and Chemical Composition of Swedenborgite, *Kungl. Svenska Vetenskapsakad. Handl. III,* 11, No. 4, 3. 4. (with an analysis by R. Blix). On the Minerals "Weslienite" and Atopite, *ibid. Handl. III,* 11, No. 4, 14. 5. Lattice Dimensions of the Mineral Armangite, *ibid. Handl. III,* 11, No. 4, 19. 6. Symmetry and Lattice Dimensions of Thaumasite, *ibid. Handl. III,* 11, No. 4, 21. 7. (with an analysis by R. Blix). On the Mineral Adelite and its Relation to Tilasite, *ibid. Handl. III,* 11, No. 4, 24.

9. **Andersen, O. and Lee, H. C.** Properties of Tricalcium Silicate from Basic Open Hearth Steel Slags, *J. Washington Acad. Sci.* 23, 338.

10. **Anderson, H. V. and Chesley, K. G.** X-ray Study of the Transformation of Marcasite into Pyrite, *Am. J. Sci.* 25, 315.

11. **Andrews, A. I. and Breen, J. P.** X-ray Investigation of the Opacifying Compounds Present in Sheet Iron Cover Enamels, *J. Am. Ceram. Soc.* 16, 325.

12. **Andrews, A. I., Clark, G. L. and Alexander, H. W.** The Determination by X-ray Methods of Crystalline Compounds Causing Opacity in Enamels, *J. Am. Ceram. Soc.* 16, 385.

13. **Astbury, W. T.** The X-ray Interpretation of Fiber Structure, *J. Soc. Dyers and Colourists, June* 1933, p. 169. 14. The X-ray Interpretation of Fiber Structure, *Sci. Progress* No. 110, 210. 15. Some Problems in the X-ray Analysis of the Structure of Animal Hairs and Other Protein Fibers, *Trans. Faraday Soc.* 29, 193. **15a.** "Fundamentals of Fiber Structure," London (1933).

16. **Astbury, W. T. and Atkin, W. R.** X-ray Interpretation of the Molecular Structure of Gelatin, *Nature* 132, 348.

17. **Astbury, W. T. and Woods, H. J.** X-ray Studies of the Structure of Hair, Wool and Related Fibers II. The Molecular Structure and Elastic Properties of Hair Keratin, *Phil. Trans. Roy. Soc. London* 232A, 333.

18. **Atsuki, K. and Ishiwara, M.** The Structure of Cellulose Gel V. The Structure of Natural Cellulose Fiber Revealed by X-ray Analysis, *J. Soc. Chem. Ind. Japan* 36, *Suppl. binding,* 517. 19. VI. The Structure of Viscose Silk and Cellophane Analyzed by X-ray, *ibid.* 36, *Suppl. binding* 521. 20. VII. The X-ray Study of Cellulose Nitrate Gel, *ibid.* 36, *Suppl. binding* 540.

21. **Audibert, É. and Raineau, A.** The Physical State of Solid Catalysts, *Ann. combustibles liquides* 8, 1147; *Compt. rend.* 197, 596.

22. **Bakhmetev, E. F., Vozdvizhenskii, M. D., Gubkin, S. I., Kosolapov, G. F. and Rovinskii, B. M.** X-ray Investigation of the Nature of Change of Structure in a Metal, Resulting from Deformation at High Temperatures, *Mitt. Forschungsinst. Luftfahrtmaterialprüfung (U.S.S.R.)* No. 1.

23. **Banerjee, K.** Determinations of the Signs of the Fourier Terms in Complete Crystal Structure Analysis, *Proc. Roy. Soc.* (*London*) 141A, 188.

24. **Bannister, F. A.** The Identity of Mottramite and Psittacinite with Cupriferous Descloizite, *Mineralog. Mag.* 23, 376.

25. **Barnes, W. H. and Wendling, A. V.** An X-ray Method for Distinguishing between Certain Space Groups in the Hexagonal System, *Trans. Roy. Soc. Can.* 27, *Sect.* 3, 133. 26. The Space Group of Tourmaline, *ibid.* 27. *Sect.* 3, 169.

27. **Baroni, A.** Alloys of Lithium II. X-ray Analysis of the System Lithium-Cadmium, *Rendiconti accad. Lincei* 18, 41.

28. **Barrett, C. S.** X-ray Studies on Lead-acid Storage Batteries, *Ind. Eng. Chem.* 25, 297. 29. The Nature of the Solid Solution of Aluminum in Silver, *Metals and Alloys* 4, 63.

Year 1933

30. **Barth, T. F. W.** The Formula of Haüynite, *Centr. Mineral. Geol.* 1933A, 316.

31. **Barth, T. F. W. and Ksanda, C. J.** Crystallographic Data on Mellite, *Am. Mineral.* 18, 8.

32. **Barth, T. F. W. and Tunell, G.** The Space Lattice and Optical Orientation of Chalchanthite. An Illustration of the Use of the Weissenberg X-ray Goniometer in the Triclinic System, *Am. Mineral.* 18, 187.

33. **Baudisch, O. and Welo, L. A.** Formation of α-Fe_2O_3 from γ-$Fe_2O_3 \cdot H_2O$ by Grinding, *Naturwiss.* 21, 593. 34. Magnetic and X-ray Studies of the Aging of Ferrous Hydroxide, *ibid.* 21, 659.

35. **Becker, K.** Physical Characteristics of High-melting Compounds, *Physikal. Z.* 34, 185.

36. **Benjamin, M. and Rooksby, H. P.** Emission from Oxide-coated Cathodes, *Phil. Mag.* 15, 810.

37. **Berl, E. and Reinhardt, L.** Nature of Activated Carbons II, *Z. physik. Chem.* 166A, 81.

38. **Berl, E. and Schmitt, B.** X-ray Spectroscopic Experiments on Orientation of Palmitic Acid on Mineral Surfaces, *Kolloid-Z.* 65, 261.

39. **Bernal, J. D. and Crowfoot, D.** Crystal Structure of Vitamin B_1 and of Adenine Hydrochloride, *Nature* 131, 911. 40. The Structure of the Diels' Hydrocarbon $C_{18}H_{16}$, *J. Soc. Chem. Ind.* 52, *Chem. Ind.* 729. 40a. Crystalline Phases of Some Substances Studied as Liquid Crystals, *Trans. Faraday Soc.* 29, 1032.

41. **Berraz, G.** Synthesis of Cuprous Nitride by Cathodic Sputtering of Copper in Nitrogen at Reduced Pressures, *Anales inst. investigaciones cient. tecnol. (Univ. nacl. litoral)* 2, 70.

42. **Bigelow, M. H. and Silverman, A.** Selenium Ruby Glass; Preparation and X-ray Study, *J. Am. Ceram. Soc.* 16, 214.

43. **Bijvoet, J. M. and Nieuwenkamp, W.** The "Variable Structure" of Cadmium Bromide, *Z. Krist.* 86, 466. 44. Crystal Structure of the Dihalides, *Chem. Weekblad* 30, 479.

45. **Biltz, W.** Rhenium Trioxide and Rhenium Dioxide. *Z. anorg. Chem.* 214, 225.

46. **Biscoe, J. and Warren, B. E.** The Structure of Euclase, *Z. Krist.* 86, 292.

47. **Bjurström, T.** X-ray Analysis of the Iron-Boron, Cobalt-Boron and Nickel-Boron Systems, *Arkiv. Kemi Mineral. Geol.* 11A, No. 5.

48. **Blake, F. C.** Factors Affecting the Reflection Intensities by the Several Methods of X-ray Analysis of Crystal Structures, *Rev. Mod. Physics* 5, 169.

49. **Blank, F.** The Mosaic Structure of Crystals, *Physikal. Z.* 34, 353.

50. **Blatchford, A. H.** The Diffraction of X-rays by Liquid Sulfur, *Proc. Phys. Soc. London* 45, 493.

51. **Blechschmidt, E. and Boas, W.** Laue Photographs of Oscillating Quartz Rods, *Z. Krist.* 85, 329.

52. **Blum, H.** Crystal Structure of Water-free Magnesium Iodide and Calcium Iodide, *Z. physik. Chem.* 22B, 298.

53. **Bødtker-Naess, G. and Hassel, O.** Lattice Dimensions and Interatomic Distances of Werner Coordination Compounds that Crystallize with the Fluorite Structure, *Norske Videnskaps-Akad. Oslo I. Mat. naturv. Kl.* 1933, No. 4. 54. Interionic Distances in Crystals of Complex Salts Having the Fluorite Structure, *ibid.* 1933, No. 7. 55. Atomic Distances in Werner Coordination Compounds II. Some Hexammino- and Hexamethylamino-halides of Bivalent Cobalt and Bivalent Nickel of the Fluorite Type, *Z. anorg. Chem.* 211, 21. 56. Effective Radius of Hexammine Cations $Me(NH_3)_6$ in Crystals of Fluorite Type, *Z. physik. Chem.* 22B, 471.

57. **Boehm, G.** X-ray Diagrams of Nerves, *Kolloid-Z.* 62, 22.

58. **Borén, B.** X-ray Study on Alloys of Silicon with Chromium, Manganese, Cobalt and Nickel, *Arkiv. Kemi Mineral. Geol.* 11A, No. 10.

59. **Borrmann, G. and Seyfarth, H.** Precision Measurements of the Lattice Constants of Carborundum, *Z. Krist.* 86, 472.

60. **Bowen, N. L., Schairer, J. F. and Posnjak, E.** The System CaO-FeO-SiO_2, *Am. J. Sci.* 26, 193.

61. **Bradley, A. J.** The Crystal Structure of Alloys, *Sci. Progress* 28, 253.

62. **Bradley, A. J. and Jay, A. H.** Quartz as a Standard for Accurate Lattice Spacing Measurements, *Proc. Phys. Soc. London* 45, 507.

63. **Bradley, A. J. and Jones. P.** An X-ray Investigation of the Copper-Aluminum Alloys, *J. Inst. Metals* 51, 131.

Year 1933

64. **Braekken, H.** Crystal Structure of Phosphorus Triiodide, *Kong. Norske Videnskabers Selskab Forh.* 5, No. 52, 202.

65. **Bragg, W. H.** Crystals of the Living Body, *Proc. Roy. Inst. Gt. Britain* 27, 606; *Nature* 132, 11, 50.

66. **Bragg, W. L.** The X-ray Microscope, *Anales soc. españ. fís. quím.* 31, 399. 67. Structure of Alloys, *Proc. Roy. Inst. Gt. Britain March 17 (preprint).* 68. Development of X-ray Analysis of Crystals, *Uspekhi Fiz. Nauk* 13, 195.

69. **Bramlette, M. N. and Posnjak, E.** Zeolitic Alteration of Pyroclastics, *Am. Mineral.* 18, 167.

70. **Brandenberger, E.** Investigation of the Crystal Structure of Calcium Aluminate Hydrates, *Schweiz. Mineralog. Petrograph. Mitt.* 13.

71. **Brasseur, H.** The Structures of Azurite and Malachite, *Thesis Presented to the Faculty of Sciences, Univ. Liége.*

72. **Brasseur, H. and de Rassenfosse, A.** Contribution to the Knowledge of the Structure of Hydrated Barium Platinocyanide, *Mem. Soc. roy. Sci. Liége* 18, 1.

73. **Bredig, M. A., Franck, H. H. and Füldner, H.** Compounds of Calcium Oxide and Phosphoric Acid II. 1. Structural Chemistry of Apatite Groups. 2. Characteristic Sensitiveness of $\alpha \rightleftarrows \beta$ Compounds of Tricalcium Phosphate with Calcium Oxide and Water Vapor, *Z. Elektrochem.* 39, 959.

74. **Brindley, G. W.** The Reflection and Refraction of X-rays by Perfect Crystals, *Proc. Roy. Soc. (London)* 140A, 301.

75. **Broch, E.** The Crystal Structure of Yttrium Vanadate, *Z. physik. Chem.* 20B, 345.

76. **Broniewski, W. and Smolinski, J.** The Structure of Iron-Nickel Alloys, *Compt. rend.* 196, 1793.

77. **Brown, F. W.** Charge Distributions in Fluorine and Neon, *Phys. Rev.* 44, 214.

78. **Brown, F. W., Bartlett, J. H., Jr. and Dunn, C. G.** Charge Distributions for the Normal Atoms from Boron to Neon, *Phys. Rev.* 44, 296.

79. **Burckhardt, J. J.** The Theory of Groups of Movements, *Comment. Math. Helv.* 6, 159.

80. **Burgers, W. G.** X-ray Investigation of the Behavior of BaO-SrO Mixtures on Ignition, *Z. Physik* 80, 352.

81. **Buschendorf, F.** The Crystal Structure of Silver Perrhenate, *Z. physik. Chem.* 20B, 237.

82. **Büssem, W. and Gross, F.** The Structure and Gas Content of Nickel Foil Made by Cathode Sputtering, *Z. Physik* 86, 135.

83. **Büssem, W. and Gottfried, C.** The Structure of Rubidium Ferricyanide, *Z. Krist.* 84, 317.

84. **Cabicar, F.** The Chemistry of Crystals and its Tendencies, *Chem. Listy* 26, 621.

85. **Caglioti, V.** X-ray Investigations on Zinc-Nickel Alloys, *Atti IV cong. naz. chim. pura appl.* 1933, 431. 85a. The Structure of Cold Worked Silver Chloride and its Recrystallization, *Rendiconti accad. Lincei* 18, 570; *Gazz. chim. ital.* 64, 39 (1934).

86. **Caglioti, V. and Centola, G.** Polyhalides II. The Thermal Decomposition of $KICl_4$ and the Stability of Compounds of the Type $MeICl_4$ and $MeICl_2$, *Gazz. chim. ital.* 63, 907.

87. **Cairns, R. W. and Ott, E.** X-ray Studies of the System Nickel-Oxygen-Water I. Nickelous Oxide and Hydroxide, *J. Am. Chem. Soc.* 55, 527. 88. II. Compounds Containing Trivalent Nickel, *ibid.* 55, 534.

89. **Champetier, G.** Addition Compounds of Cellulose, *Ann. chim.* 20, 5. 90. The Action of Orthophosphoric Acid on Ordinary Cellulose, *Compt. rend.* 196, 930.

91. **Chapman, E. P. and Stevens, R. E.** Silver- and Bismuth-bearing Galena from Leadville, *Econ. Geol.* 28, 678.

92. **Charmadarjan, M. O. and Markow, W. K.** Effect of the Reaction of the Medium at the Moment of Coagulation on the Structure of Silica Gel I, *Physikal. Z. Sowjetunion* 4, 172; *Ukrainskii Khem. Zhur.* 8, *Sci. Part* 1.

93. **Chrobak, L.** X-ray Scattering Power of Metallic Silver for K-α Copper Radiation, *Z. Krist.* 84, 475.

94. **de la Cievera, P. and Losada, J.** Photometric Methods of Reflection of X-rays I. Comparison of Reflective Powers of Two Crystals, by Means of a Standard Substance, *Anales soc. españ. fís. quím.* 31, 607.

Year 1933

95. **Claassen, A. and Burgers, W. G.** X-ray Proof of the Compound ZrW_2, *Z. Krist.* 86, 100.

96. **Clark, G. L.** A Decade of Applied X-ray Research: Grasselli Medal Address, *J. Soc. Chem. Ind.* 52, *Chem. Ind.* 317, 336. 97. Industrial Radiology, "The Science of Radiology," Chap. 21, p. 354.

98. **Clark, G. L. and Mrgudich, J. N.** X-ray Studies of the Insulating Materials in High-tension Cables, *Elec. Eng.* 52, 101.

99. **Clark, G. L. and Smith, H. A.** Occurrence of $CuAl_2$ in Duralumin, *Phys. Rev.* 43, 305.

100. **Colby, M. Y. and Harris, S.** Effect of Etching on the Relative Intensities of the Components of Double Laue Spots Obtained from a Quartz Crystal, *Phys. Rev.* 43, 562.

101. **Colby, M. Y. and LaCoste, L. J. B.** The Crystal Structure of Cerussite, *Z. Krist.* 84, 299.

102. **Corey, R. B. and Wyckoff, R. W. G.** On the Structure of Tetragonal $NiSO_4 \cdot 6H_2O$, *Z. Krist.* 84, 477. 103. On the Structure of Methyl Urea, *ibid.* 85, 132. 104. The Crystal Structure of Zinc Hydroxide, *ibid.* 86, 8.

105. **Correns, C. W. and Nagelschmidt, G.** The Fiber Structure and Optical Properties of Chalcedony, *Z. Krist.* 85, 199.

106. **Coster, D. and Knol, K. S.** The Atomic Scattering Factor for X-rays in the Region of Anomalous Dispersion, *Proc. Roy. Soc.* (*London*) 139A, 459.

107. **Coster, D. and van der Ziel, A.** A Photochemical Process for Monoalkyl Malonic Acids, *Z. physik. Chem.* 20B, 385.

108. **Cox, E. G. and Goodwin, T. H.** Preliminary Data for Some Sugar Derivatives, *Z. Krist.* 85, 462.

109. **Cox, E. G. and Preston, G. H.** The Molecular Structure of Some Coordination Compounds of Platinum and Palladium, *J. Chem. Soc.* 1933, 1089.

110. **Damianovich, H.** Inertia and Chemical Activity of Rare Gases V. X-ray Spectrogram of Cathodic Deposits of the Platinum-Helium Combination with Excess of Platinum—the Special Case of Amorphous Compounds, *Anales inst. investigaciones cient. tecnol.* (*Univ. nacl. litoral*) 2, 24.

111. **Danilow, W., Finkelstein, W. and Sirotenko, D.** The Scattering of X-rays by Solutions of Heavy Molecules and the Structure of Complex Ions, *Physikal. Z. Sowjetunion* 3, 653.

112. **Danilow, W., Kurdjumow, G., Pluschnik, E. and Stellezky, T.** Ferromagnetism of Trigonal Ferric Oxide, *Naturwiss.* 21, 177.

113. **Dehlinger, U.** Structure of Crystals I, *Physik regelmässig. Ber.* 1, 7. 114. Laws of Transformation in the Solid State of Metals, *Metallwirtschaft* 12, 207.

115. **Dehlinger, U., Osswald, E. and Bumm, H.** Transformation in Single Crystals of Cobalt, *Z. Metallkunde* 25, 62.

116. **Dehlinger, U. and Wiest, P.** Does the Change of Lattice Constants during the Formation of Solid Solutions Depend on Grain Size? *Metallwirtschaft* 12, 2.

117. **Dennis, L. M. and Rochow, E. G.** Oxyacids of Fluorine II, *J. Am. Chem. Soc.* 55, 2431.

118. **Drier, R. W. and Walker, H. L.** An X-ray Investigation of the Gold-Rhodium and Silver-Rhodium Alloys, *Phil. Mag.* 16, 294.

119. **Du Bois.** The Dependence of Corrosion Velocity of Copper upon the Thermal and Mechanical Pretreatment of the Copper, *Oberflächentech.* 10, 235.

120. **Ebert, F. and Cohn, E.** The Ceramics of Highly Refractory Materials VI. The System: ZrO_2-MgO, *Z. anorg. Chem.* 213, 321.

121. **Ebert, F., Hartmann, H. and Peisker, H.** $\alpha \rightleftarrows \beta$ Transition of Calcium, *Z. anorg. Chem.* 213, 126.

122. **Ebert, F. and Woitinek, H.** Crystalline Structure of Fluorides II. HgF, HgF_2, CuF and CuF_2, *Z. anorg. Chem.* 210, 269.

123. **Eckell, J.** Relationships between Structure of Catalyst and Chemical Change III, *Z. Elektrochem.* 39, 807, 855.

124. **Edwards, J. D. and Tosterud, M.** The Oxides and Hydrates of Aluminum, *J. Phys. Chem.* 37, 483.

125. **Ehret, W. F. and Westgren, A.** X-ray Analysis of Iron-Tin Alloys, *J. Am. Chem. Soc.* 55, 1339.

126. **Engel, G.** The Crystal Structures of Some Compounds of the K_2PtCl_6-type, *Naturwiss.* 21, 704.

Year 1933

127. **Ernst, T.** Preparation and Crystal Structure of Lithium Hydroxide, *Z. physik. Chem.* 20B, 65.

128. **Esser, H. and Mueller, G.** The Lattice Constants of Pure Iron and Iron-Carbon Alloys at Temperatures up to 1100°, *Arch. Eisenhüttenw.* 7, 265.

129. **Ewald, P. P.** Investigation of the Structure of Matter by Means of X-rays, *Handbuch Physik* 23, *Part 2,* 207.

130. **Faber, W.** Niccolite, *Z. Krist.* 84, 408.

131. **Feitknecht, W.** The Structure of the Basic Salts of Bivalent Metals, *Helv. Chim. Acta* 16, 427.

132. **Ferrari, A. and Colla, C.** Iridionitrites of Ammonium, Potassium, Rubidium, Cesium, Thallium and Barium, *Gazz. chim. ital.* 63, 507. 133. Chemical and Crystallographic Studies on Ammonium, Potassium, Rubidium, Cesium and Thallium Cobaltinitrites, *Rendiconti accad. Lincei* 17, 390. 134. Rhodionitrites of Ammonium, Potassium, Rubidium, Cesium, Thallium, Barium and Lead, *ibid.* 18, 45.

135. **Ferrari, A. and Curti, R.** Chemical and Crystallographic Investigations on Nickelonitrites of Bivalent Metals, *Gazz. chim. ital.* 63, 495.

136. **Fonda, G. R.** Effect of Particle Size on Intensity in X-ray Spectroscopic Analysis, *J. Am. Chem. Soc.* 55, 123.

137. **Franck, H. H., Bredig, M. A. and Hoffmann, G.** The Crystal Structure of Calcium-Nitrogen Compounds, *Naturwiss.* 21, 330.

138. **Fricke, R. and Ackermann, P.** X-ray and Thermal Characteristics of Progressive Lattice Formation of Zinc Oxide, *Naturwiss.* 21, 366. 139. Thermal and X-ray Characterization of Lattice Distortions in Zinc Oxide, *Z. anorg. Chem.* 214, 177.

140. **Fricke, R. and Lüke, J.** Energy Content, Particle Dimension and Lattice Formation of Active Beryllium Oxide, *Z. physik. Chem.* 23B, 319.

141. **Fuller, M. L. and Rodda, J. L.** Segregate Structures of the Widmanstätten Type Developed from Solid Solutions of Copper in Zinc, *Trans. Am. Inst. Min. Met. Eng.* 104, *Inst. Metals Div.* 116.

142. **Garrido, J.** The System: Bismuth-Tellurium-Sulfur. Oruetite, an X-ray Study, *Anales soc. españ. fís. quím.* 31, 99. 142a. Crystal Structure of Ammonium Iodate, *Bull. soc. franç. mineral.* 56, 347.

143. **Garrido, J. and West, J.** Representation of Crystal Structure by the Fourier Series I. Influence of Extinction, *Anales soc. españ fís. quím.* 31, 225.

144. **Gebhardt, F., Köhler, R. and Körner, E.** Colloid Chemistry of the Trommer Sugar Test, *Kolloid-Z.* 63, 257.

145. **Girard, A. and Chaudron, G.** Crystalline Systems of Microcrystalline Ferric Oxides, *Compt. rend.* 196, 925.

146. **Glocker, R.** Principles of Quantitative X-ray Analysis of the Concentration of Metal Phases in an Alloy or Mixture, *Metallwirtschaft* 12, 599.

147. **Glocker, R. and Schäfer, K.** Determination of Atom Factors in the Region of Anomalous Dispersion, *Naturwiss.* 21, 559.

148. **Goldschmidt, V.** An Apparatus for Laue Diagrams and Reflection Photography, *Centr. Mineral. Geol.* 1933A, 49.

149. **Goldsztaub, S.** Crystal Structure of Sodium Ferrite, *Compt. rend.* 196, 280.

150. **Gossner, B. and Baüerlein, Th.** Optical Anomalies: Voltaite-like Sulfates, *Neues Jahrb. Mineral. Geol. Beilage-Bd.* 66A, 1.

151. **Gossner, B. and Drexler, K.** Structural and Molecular Units of Sulfates of the Voltaite Type, *Centr. Mineral. Geol.* 1933A, 83.

152. **Gossner, B. and Kraus, O.** The Chemical Composition of Wöhlerite, *Z. Krist.* 86, 308. 153. The Crystal Form and Molecular Unit of Rinkite, *Centr. Mineral. Geol.* 1933A, 369.

154. **Gossner, B. and Neff, H.** Crystals of Hydrochlorides, Hydrobromides and Hydroiodides of Ephedrine and Pseudoephedrine, *Z. Krist.* 85, 370. 155. Crystals of Hydrochlorides, Hydrobromides and Hydroiodides of d- and l-Ephedrine and d- and l-Pseudoephedrine, *ibid.* 86, 32.

156. **Graf, L.** X-ray Examination of Calcium at Elevated Temperatures, *Metallwirtschaft* 12, 649.

157. **Greenwood, G.** On the "Correct" Setting of Crystals, *Z. Krist.* 85, 420. 158. The Debye-Scherrer Photograph, *Indian J. Physics* 8, 269.

159. **Grime, G. and Bessey, G. E.** Cementing Material of Sand-lime Bricks. An X-ray and Microscopical Investigation, *Trans. Ceram. Soc. (England)* 32, 14.

Year 1933

160. **Gruner, J. W.** The Crystal Structure of Nacrite and a Comparison of Certain Optical Properties of the Kaolin Group with its Structures, *Z. Krist.* 85, 345.

161. **Hägg, G.** X-ray Crystallographic Investigations with Long-wave X-rays, *Z. Krist.* 86, 246. 162. Vacant Positions in the Iron Lattice of Pyrrhotite, *Nature* 131, 167.

163. **Hägg, G. and Kindström, A.** X-ray Investigation of the System Iron-Selenium, *Z. physik. Chem.* 22B, 453.

164. **Hägg, G. and Phragmén, G.** Deviation from the Bragg Equation for the Powder Method, *Z. Krist.* 86, 306.

165. **Hägg, G. and Sucksdorff, I.** The Crystal Structure of Troilite and Pyrrhotite, *Z. physik. Chem.* 22B, 444.

166. **Halla, F. and Kutzelnigg, A.** Zinc Phosphate Cement, *Z. Stomatol.* 31, 177.

167. **Halla, F., Nowotny, H. and Tompa, H.** X-ray Investigations in the System (Zinc, Cadmium)-Antimony II, *Z. anorg. Chem.* 214, 196.

168. **Hansen, M. and Stenzel, W.** The Solubility of Copper in Zinc, *Metallwirtschaft* 12, 539.

169. **Harker, G. F. H.** A Direct Determination of the Indices and Locations of the Spots in a Laue Pattern of Calcite, *Phil. Mag.* 15, 512.

170. **Hartree, D. R.** Results of Calculations of Atomic Wave Functions I. Survey and Self-consistent Fields for Cl^- and Cu^+, *Proc. Roy. Soc.* (*London*) 141A, 282.

171. **Harvey, G. G.** Diffuse Scattering of X-rays from Sylvine II, *Phys. Rev.* 43, 591. 172. III. Scattering at the Temperature of Liquid Air, *ibid.* 43, 707. 173. IV. Scattering at High Temperatures, *ibid.* 44, 133.

174. **Hassel, O.** The Crystal Structure of Cadmium Iodide, *Z. physik. Chem.* 22B, 333.

175. **Haworth, W. N. and Hirst, E. L.** Synthesis of Ascorbic Acid, *J. Soc. Chem. Ind.* 52, *Chem. Ind.* 645.

176. **Hedvall, J. A., Hedin, R. and Anderson, E.** The Question of the "Transformation Points" of Bismuth and Copper, *Z. anorg. Chem.* 212, 84.

177. **Heil, L. M. and Edwards, J. E.** The Measurement of X-ray Absorption Coefficients by the Use of the FP-54 Pliotron, *Phys. Rev.* 43, 1.

178. **Hellström, K. and Westgren, A.** Rhombic Chromium Carbide Crystal Structure, *Svensk Kem. Tids.* 45, 141.

179. **Hendricks, S. B.** The Crystal Structure of $CaSO_4 \cdot CO(NH_2)_2$, *J. Phys. Chem.* 37, 1109.

180. **Hendricks, S. B., Deming, W. E. and Jefferson, M. E.** The Refractive Indices of Ammonium Nitrate, *Z. Krist.* 85, 143.

181. **Hendricks, S. B., Maxwell, L. R., Mosley, V. L. and Jefferson, M. E.** X-ray and Electron Diffraction of Iodine and the Diiodobenzenes, *J. Chem. Phys.* 1, 549.

182. **Heritsch, H.** X-ray Investigation of a Garnet from near Spittal, Kärnten (Austria), *Z. Krist.* 85, 392.

183. **Herrmann, K.** Inclination of Molecules in Some Crystalline-fluid Substances, *Trans. Faraday Soc.* 29, 972.

184. **Hertel, E. and Römer, G. H.** The Crystal Structure of Terphenyl, *Z. physik. Chem.* 21B, 292. 185. The Fine Structure of Trinitrobenzene Derivatives, *ibid.* 22B, 267. 186. Crystal Structure of a New Type of Molecular Compound, *ibid.* 22B, 280. 187. The Fine Structure of the Isomeric Hydrocarbons Quaterphenyl and Triphenylbenzene, *ibid.* 23B, 226.

188. **Hess, K.** The Structure of the High-molecular Organic Natural Substances, *Chem. Weekblad* 30, 619.

189. **Hess, K. and Trogus, C.** X-ray Investigation of Proteins II. Studies on Gelatin, *Biochem. Z.* 262, 131. 190. Remarks on the Work of W. Schramek: "The X-ray Fiber Diagram as a Quantitative Measure for the Change of Building Units of Cellulose Fibers by Chemical Processes," *Z. physik. Chem.* 21B, 349.

191. **Hess, K., Trogus, C. and Dziengel, K.** Relation between Cellulose and Cellulosedextrins II. Crystallization of Nitrocellulose, *Ann. Chem.* (*Liebig's*) 501, 49.

192. **Heusler, O.** Crystal Structure and Ferromagnetism of Manganese-Aluminum-Copper Alloys, *Z. Metallkunde* 25, 274. 193. Lattice Structure and Ferromagnetism in Manganese-Aluminum-Copper Alloys II. Magnetic and Electric Investigations, *Z. Elektrochem.* 39, 645.

194. **Hey, M. H.** Zeolites V. Mesolite, *Mineralog. Mag.* 23, 421.

Year 1933

195. **Hey, M. H. and Bannister, F. A.** Studies on the Zeolites IV. Ashcroftine (Kalithomsonite of S. G. Gordon), *Mineralog. Mag.* 23, 305.

196. **Hicks, L. C.** An X-ray Study of the Diffusion of Chromium into Iron, *Am. Inst. Min. Met. Eng., Iron Steel Div., Contrib.* No. 58.

197. **Hilpert, S. and Lindner, A.** Ferrites II. The Alkaline, Alkaline Earth and Lead Ferrites, *Z. physik. Chem.* 22B, 395.

198. **Hoard, J. L.** An X-ray Investigation of the 12-Molybdophosphates and Related Compounds, *Z. Krist.* 84, 217. 199. The Crystal Structure of Potassium Silver Cyanide, *ibid.* 84, 231.

200. **Hoard, J. L. and Dickinson, B. N.** The Crystal Structure of Potassium Bromoselenite, *Z. Krist.* 84, 436.

201. **Hocart, R.** Boracite Symmetry and X-rays, *Compt. rend.* 196, 789.

202. **Hönl, H.** The Scattering of X-rays by Atoms as a Problem in Dispersion Theory, *Ann. Physik* 18, 625. 203. The Theory of X-ray Dispersion, *Z. Physik* 84, 1. 203a. Atomic Scattering Factors for X-rays as a Problem of the Dispersion Theory (for the K-Levels), *Ann. Physik* 18, 625.

204. **Hoffmann, A.** Difference in Size of the Ions of Zirconium and Hafnium, *Naturwiss.* 21, 676.

205. **Hofmann, U., Endell, K. and Wilm, D.** The Crystal Structure and the Swelling of Montmorillonite, *Z. Krist.* 86, 340.

206. **Hofmann, W.** Structural and Morphological Relationships of Ores of the Type ABC_2 I. The Structures of Wolfsbergite and Emplectite and their Relation to Stibnite, *Z. Krist.* 84, 177. 207. The Structure of the Minerals of the Stibnite Group, *ibid.* 86, 225.

208. **Van Horn, F. R. and Van Horn, K. R.** X-ray Study of Pyrite or Marcasite Concretions in the Rocks of the Cleveland, Ohio, Quadrangles, *Am. Mineral* 18, 288.

209. **Hüttig, G. F., Kittel, H. and Herrmann, Z.** Active Oxides LXIX. Changes in Magnetic Properties Observed in an Intimate Mixture of Oxides of Beryllium and Iron during Heating, *Gazz. chim. ital.* 63, 833.

210. **Huggins, M. L.** The Crystal Structure of Potassium Dithionate, *Z. Krist.* 86, 384. 211. The Crystal Structure of Potassium Dithionate, *Am. Mineral.* 18, 455.

212. **Huggins, M. L. and Mayer, J. E.** Interatomic Distances in Crystals of the Alkali Halides, *J. Chem. Phys.* 1, 643.

213. **Hutino, K.** Direction of Growth of Needles of Glucose Pentaacetate and Cellobiose Octaacetate, *Bull. Inst. Phys. Chem. Research (Tokyo)* 12, 722; *Sci. Pap. Inst. Phys. Chem. Research (Tokyo)* 21, Nos. 440-7, 270-2.

214. **Iball, J. and Robertson, J. M.** Structure of Chrysene and 1,2,5,6-Dibenzanthracene in the Crystalline State, *Nature* 132, 750.

215. **Ireton, H. J. C., Blewett, J. P. and Allen, J. F.** X-ray Analysis of the Crystal Structure of the Thallium-Tin Alloys, *Can. J. Research* 9, 415.

216. **Ito, T.** A Possible Form of Si_3O_8 Groups in Silicates, *Proc. Imp. Acad. Tokyo* 9, 53. 217. The Si_3O_8-chains in Space Groups V_h^{16} and C_{2h}^5, *ibid.* 9, 528.

218. **Ivannikov, P. Y., Frost, A. V. and Shapiro, M. I.** The Effect of Ignition Temperature on the Catalytic Activity of Zinc Oxide, *Compt. rend. acad. sci. (U.R.S.S.)* 1933, 124.

219. **Iwasê, K. and Nasu, N.** X-ray Study on the Electrolytic Fe-Ni Alloys, *Sci. Repts. Tôhoku Imp. Univ.* 22, 328.

220. **Jackson, W. W. and West, J.** The Crystal Structure of Muscovite, *Z. Krist.* 85, 160.

221. **Jacobson, B. and Westgren, A.** Nickel Carbide and its Relation to the Other Carbides of the Series of Elements, Scandium-Nickel, *Z. physik. Chem.* 20B, 361.

222. **Jaeger, F. M. and Beintema, J.** The Crystal Structure of Cesium, Thallium and Rubidium Perrhenates, *Proc. Acad. Sci. Amsterdam* 36, 523.

223. **Jaeger, F. M. and Bottema, J. A.** The Exact Determination of Specific Heats at Elevated Temperatures IV. Law of Neumann-Joule-Kopp-Regnault concerning the Additive Property of Atomic Heats of Elements in their Chemical Combinations, *Rec. trav. chim.* 52, 89.

224. **Jaeger, F. M. and Zanstra, J. E.** The Allotropism of Beryllium, *Proc. Acad. Sci. Amsterdam* 36, 636.

225. **Jansen, W.** X-ray Investigation concerning the Crystal Orientation in

Spherulites, *Z. Krist.* 85, 239. 226. X-ray Investigation of Crystal Orientation in (Parallel) Fibrous Aggregates, *ibid.* 86, 171.

227. **Jauncey, G. E. M. and Pennell, F.** Scattering of X-rays from Powdered Crystals, *Phys. Rev.* 43, 505. 228. Scattering of X-rays from Powdered Crystals at Low Temperatures, *ibid.* 44, 138.

229. **Jauncey, G. E. M. and Williams, P. S.** Diffuse Scattering of X-rays from Sodium Fluoride II. Scattering at the Temperature of Liquid Air, *Phys. Rev.* 44, 794.

230. **Jay, A. H.** A High-temperature X-ray Camera for Quantitative Measurements, *Z. Krist.* 86, 106. 231. A High-temperature X-ray Camera for Precision Measurements, *Proc. Phys. Soc. London* 45, 635. 232. The Thermal Expansion of Quartz by X-ray Measurements, *Proc. Roy. Soc.* (*London*) 142A, 237.

233. **Jenkins, W. J.** Function of Plasticizers in Cellulose Derivatives, *Ind. Chem.* 9, 204.

234. **Jette, E. R. and Foote, F.** An X-ray Study of the Wüstite (FeO) Solid Solutions, *J. Chem. Phys.* 1, 29. 235. A Study of the Homogeneity Limits of Wüstite by X-ray Methods, *Trans. Am. Inst. Min. Met. Eng.* 105, *Iron Steel Div.* 276.

236. **Jette, E. R. and Gebert, E. B.** An X-ray Study of the Binary Alloys of Silicon with Ag, Au, Pb, Sn, Zn, Cd, Sb and Bi, *J. Chem. Phys.* 1, 753.

237. **Jette, E. R. and Greiner, E. S.** An X-ray Study of Iron-Silicon Alloys Containing 0 to 15 per cent Silicon, *Am. Inst. Min. Met. Eng., Iron Steel Div., Contrib.* No. 8.

238. **Johansson, A. and Westgren, A.** Determination of the Phase Boundary Lines of the Copper-Zinc Diagram by X-rays, *Metallwirtschaft* 12, 385.

239. **Johnson, B. L.** A Study of the Aging of Rubber, *J. Elisha Mitchell Sci. Soc.* 49, 39.

240. **Jolibois, P. and Fouretier, G.** X-ray Crystal Analysis of Unstable Precipitates, *Compt. rend.* 197, 1322.

241. **Jost, W.** The Rate of Diffusion of a Few Metals in Gold and Silver, *Z. physik. Chem.* 21B, 158.

242. **Kalkbrenner, H. and Schiebold, E.** The Refraction of X-rays in the Service of Biology and Medicine, *Fortschr. Geb. Röntgenstrahlen* 47, 694.

243. **Kast, W.** Comparison of X-ray Diagram of Crystalline-liquid and Normal-liquid Phases of the Same Substance, *Naturwiss.* 21, 737.

244. **Katz, J. R.** X-ray Introduction to the Cellulose Symposium, *Chem. Weekblad* 30, 26.

245. **Katz, J. R. and de Rooy, A.** Crystallinity of Fibrin, *Naturwiss.* 21, 559. 246. The X-ray Diagram of Fibrin, *Rec. trav. chim.* 52, 742.

247. **Katzoff, S. and Ott, E.** On the Lattice Constants of Ferric Oxide, *Z. Krist.* 86, 311.

248. **Keggin, J. F.** Structure of the Molecule of 12-Phosphotungstic Acid, *Nature* 131, 908. 249. Structure of the Crystals of 12-Phosphotungstic Acid, *ibid.* 132, 351.

250. **Kelley, W. P. and Dore, W. H.** The Nature of the Base-exchange Material of Soils and of the Bentonitic Clays as Revealed by Chemical Investigations and X-ray Analysis, *Trans. 2nd Intern. Cong. Soil Sci., Leningrad 1930*, 2, 34.

251. **Kempf, L. W.** Occurrence of $CuAl_2$ in Duralumin, *Phys. Rev.* 43, 942.

252. **Kersten, H. and Lange, W.** A Needle Valve for Gas X-ray Tubes, *Rev. Sci. Instruments* 4, 332.

253. **Kersten, H. and Maas, J.** The Crystal Structure of Precipitated Copper-Tin Alloys, *J. Am. Chem. Soc.* 55, 1002. 254. A Calcium Target for X-ray Tubes, *Rev. Sci. Instruments* 4, 381.

255. **Ketelaar, J. A. A.** The Crystal Structure of the Aluminum Halides I. The Structure of Aluminum Trifluoride, *Z. Krist.* 85, 119.

256. **Khouvine, Y. and Nitzberg, G.** Identification and Biochemical Oxidation for α-Glucoheptulitol, *Compt. rend.* 196, 218.

257. **Kinsey, E. L. and Sponsler, O. L.** The Molecular Structure of Ice and Liquid Water, *Proc. Phys. Soc. London* 45, 768.

258. **Kirkpatrick, P. and Ross, P. A.** Absolute X-ray Reflectivities of Single Crystals of Calcite, Rocksalt, Rochelle Salt and Barite, *Phys. Rev.* 43, 596.

259. **Kittel, H., Hüttig, G. F. and Herrmann, Z.** Active Oxides LIX. Changes in the Magnetic and X-ray Spectrographic Properties during the Transformation of a Mixture of Zinc Oxide and Ferric Oxide into Spinel, *Z. anorg. Chem.* 210, 26. 260. LXIV. Alterations of the Magnetic and X-ray Spectroscopic Properties during

the Transformation of a Mixture of Magnesium Oxide and Ferric Oxide into a Spinel, *ibid.* 212, 209.

261. **Klug, H. P.** The Crystal Structure of Potassium Thiocyanate, *Z. Krist,* **85,** 214. 262. The Crystal Structure of o-Iodobenzoic Acid, *J. Am. Chem. Soc.* **55,** 1430.

263. **Koester, W. and Schmidt, W.** The System: Iron-Cobalt-Manganese, *Arch. Eisenhüttenw.* 7, 121.

264. **Kohler, M.** The Dynamic Reflection of X-rays by Ideal, Especially Absorbent Crystals, *Ann. Physik* 18, 265.

265. **Kolkmeijer, N. H. and Favejee, J. C. L.** Structure of Emulsoid Sol Particles and their Hydration Film, *Nature* **132,** 602.

266. **Komar, A.** The Interpretation of the Asymmetrical Asterism of Laue Diagrams of Deformed Crystals of Sodium Chloride, *Physikal. Z. Sowjetunion* 4, 563.

267. **Konobejewski, S. and Selisski, I.** The Broadening of the Debye-Scherrer Lines on the X-ray Photographs of Metals after Cold Working and Annealing, *Physikal. Z. Sowjetunion* 4, 459.

268. **Konobejewski, S. and Tarassowa, W.** Transformation of the α-Phase of Copper-Tin Alloys after Deformation, *Physikal. Z. Sowjetunion* 4, 571.

269. **Kôzu, S. and Takanê, K.** Crystal Structure of Cancrinite from Dôdô, Korea I, *Proc. Imp. Acad. Tokyo* 9, 56. 270. II, *ibid.* 9, 105.

271. **Kôzu, S. and Tsurumi, S.** Triangular Biotitic Phlogopite in Basalt from Mutsuré-jima and its Chemical Composition, *Proc. Imp. Acad. Tokyo* 9, 269.

272. **Kratky, O.** The Structure of Liquid Mercury, *Physikal. Z.* 34, 482.

273. **Kreutz, St.** The Vicinal Faces of Topaz, *Bull. intern. acad. polonaise, Cl. sci. math. nat.* 1933A, 169.

274. **Krüger, F. and Gehm, G.** Change of Lattice Constants and the Conductivity of Palladium Charged Electrolytically with Hydrogen, *Ann. Physik* 16, 174. 275. Lattice Constants and Electrical Conductivity of Electrolytically Charged Palladium-Silver Alloys in Relation to the Hydrogen Charge, *ibid.* 16, 190.

276. **Ksanda, C. J. and Merwin, H. E.** Bavenite: Symmetry, Unit Cell, *Am. Mineral.* **18,** 341.

277. **Kunzl, V. and Köppel, J.** The Constant of the Crystalline Grating of the Rhombohedral Face of Quartz, *Compt. rend.* 196, 787. 278. Accurate Method of Measuring Lattice Constants, *ibid.* 196, 940.

279. **Kurdyumov, G. V.** Application of X-rays to Metallurgy, *Domez* 1933, Nos. 5-6, 34.

280. **Kutzelnigg, A. and Wagner, W.** Colloidal Alumina-Copper Chloride Systems, Formed by the Action of Alcoholic Copper Chloride Solutions on Aluminum, *Kolloid-Z.* 64, 209.

281. **Laves, F.** The Crystal Structure and Morphology of Gallium, *Z. Krist.* 84, 256. 282. Crystal Structure of Borides of the Type MeB_6, *Z. physik. Chem.* 22B, 114.

283. **LeBlanc, M. and Erler, W.** X-ray Investigations of the Mixed-crystal System Gold-Silver and the Solvent Effect of Nitric Acid on the System, *Ann. Physik* 16, 321.

284. **LeBlanc, M. and Möbius, E.** X-ray Study of the System Nickel-Oxygen-Water, *Z. Elektrochem.* 39, 753.

285. **LeBlanc, M. and Müller, R.** System: Nickel Oxide-Oxygen-Water, *Z. Elektrochem.* 39, 204.

286. **Levi, G. R. and Ghiron, D.** The Amorphous-crystalline Transformation of Arsenic and Antimony, *Rendiconti accad. Lincei* 17, 565.

287. **Levi, G. R. and Tabet, M.** Examination of Electrolytically Deposited Chromium by Use of X-rays, *Rendiconti accad. Lincei* 17, 647. 287a. Fibrous Structures in Ionic Lattices, *ibid.* 18, 574.

288. **Levin, I. and Ott, E.** X-ray Study of Opals, Silica Glass and Silica Gel, *Z. Krist.* **85,** 305.

289. **Levy, L. and West, D. W.** A New Fluorescent Screen for Visual Examination, *Brit. J. Radiology* 6, 404.

290. **Lottermoser, A. and Lottermoser, E.** Research on the Aging of Hydrated Oxides, *Kolloid. Beihefte* **38,** 1.

291. **McGarrity, W. F. and Anderson, H. V.** Effect of Normalizing on the Grain Structure and Physical Properties of Automobile Sheet Steel, *Trans. Am. Soc. Steel Treating* 21, 139.

Year 1933

292. **Mark, H.** Recent Work on the Structure of Compounds of High Molecular Weight and its Significance in the Paper Industry, *World's Paper Trade Rev. Tech. Conv.* Nos. 12-16, 66-74; *Paper Maker and Brit. Paper Trade J.* 85, 85 TS.

293. **Mathieu,** Structural Variations in the Nitrocelluloses, *Trans. Faraday Soc.* 29, 122.

294. **Mayer, J. E.** The Lattice Energies of the Silver and Thallium Halides, *J. Chem. Phys.* 1, 327.

295. **Megaw, H. D.** The Thermal Expansions of Certain Crystals with Layer Lattices, *Proc. Roy. Soc. (London)* 142A, 198.

296. **Miles, F. D.** A Pressure Regulator for Gas-filled X-ray Tubes, *Trans. Faraday Soc.* 29, 788.

297. **Miller, E. P.** A Demountable Metal X-ray Tube, *Rev. Sci. Instruments* 4, 379.

298. **Minagawa, T.** Amylosynthease XVI. X-ray Spectrography on Synthetic Starch, *J. Agr. Chem. Soc. Japan* 9, 907.

299. **Möller, H.** The Measurement of Strains by X-rays, *Z. tech. Physik* 14, 217; *Arch. Eisenhüttenw.* 5, 215 (1931-1932). 299a. Precision Measurements of Lattice Constants by Means of the Back-reflection Method, *Stahl u. Eisen* 53, 655; *Ceram. Abstr.* (in *J. Am. Ceram. Soc.*) 12, 385.

300. **Möller, H. and Trömel, G.** X-ray Study of the Structure of the Inorganic Matter of Teeth, *Naturwiss.* 21, 346.

301. **Moeller, K.** Precision Measurements of Lattice Constants by the Debye-Scherrer Method, *Naturwiss.* 21, 61. 302. A Standard Substance for Accurate Debye-Scherrer Determination of Lattice Constants, *ibid.* 21, 223.

303. **Montoro, V.** X-rays and Elastic Deformation in Metals, *G. chim. ind. appl.* 15, 8.

304. **Morral, F. R., Phragmén, G. and Westgren, A.** Carbides of Low-Tungsten and Molybdenum Steels, *Nature* 132, 61.

305. **Morse, H. W., Donnay, J. D. H. and Ott, E.** Composition and Structure of Artificial Spherulites, *Am. J. Sci.* 25, 494.

306. **Mourant, A. E.** The Dehydration of Thomsonite, *Mineralog. Mag.* 23, 371.

307. **Müller, A.** Carbon Rings XXI. X-ray Measurements of High-membered Cyclic Compounds, *Helv. Chim. Acta* 16, 155. 308. Note on the Arrangement of Chain Molecules in Liquid n-Paraffins, *Trans. Faraday Soc.* 29, 990.

309. **Nahmias, M. E.** X-ray Investigation of Tridymite Glass, *Nature* 132, 857. 310. Quantitative Crystalline Analysis by Means of X-rays, *Z. Krist.* 85, 319. 311. Bauxite and Mullite X-ray Study, *ibid.* 85, 355; *J. Am. Ceram. Soc.* 16, 420.

312. **Nakai, T. and Fukami, Y.** The X-ray Analysis of Seger Cones, *J. Soc. Chem. Ind. Japan* 36, *Suppl. binding* 170. 313. X-ray Examination of Ceramic Raw Materials, II, III and IV, V, *ibid.* 36, *Suppl. binding* 349, 434, 559, 604.

314. **Natanson, G. L.** X-ray Analysis in the Use and Study of Catalysts, *J. Chem. Ind. (U.S.S.R.)* 10, 44.

315. **Natta, G.** Structure and Polymorphism of Hydrohalic Acids, *Gazz. chim. ital.* 63, 425.

316. **Natta, G. and Baccaredda, M.** Antimony Tetroxide and the Antimonates, *Z. Krist.* 85, 271.

317. **Natta, G. and Vecchia, O.** Structure and Polymorphism of Silver Cyanide, *Gazz. chim. ital.* 63, 439.

318. **Neuburger, M. C.** The Crystal Structure and Lattice Constants of α- (β)-Tungsten, *Z. Krist.* 85, 232. 319. Precision Measurements of the Lattice Constants of Beryllium, *ibid.* 85, 325. 320. Lattice Constants, 1933, *ibid.* 86, 395. 321. Remarks on Crystal Grating Structure and Grating Constants of Mercury, *Z. anorg. Chem.* 212, 40.

322. **Neuman, E. W.** X-ray Investigation of Sodium Fluophosphate, *Z. Krist.* 86, 298.

323. **Nieuwenkamp, W.** The Chemical Composition of Matlockite, *Z. Krist.* 86, 470.

324. **Nishigôri, S.** The Equilibrium Diagram of Iron-Nitrogen Alloys, *Tech. Repts. Tôhoku Imp. Univ.* 11, 68.

325. **Nishiyama, Z.** X-ray Investigation of the Aging Effect in Quenched Carbon Steels, *Sci. Repts. Tôhoku Imp. Univ.* 22, 565.

326. **Nowakowski, A.** A Study of the Modifications of Phosphoric Anhydride by Means of X-rays, *Roczniki Chem.* 13, 346.

Year 1933

327. **Obinata, I.** X-ray Examination of Antimony-Lead and Tin-Lead Alloys, *Metallwirtschaft* 12, 101.

328. **Obinata, I. and Wassermann, G.** X-ray Study of the Solubility of Aluminum in Copper, *Naturwiss.* 21, 382.

329. **O'Daniel, H.** KFeS$_2$ and CuFeS$_2$, *Z. Krist.* 86, 192.

330. **Oguri, S.** Chemical Investigation of Bamboo X. X-ray Study of Bamboo Cellulose, *Cellulose Ind. (Tokyo)* 9, 59; *Abstr. in Eng.* 7.

331. **Ohara, K.** The Fine Structure of Silk I-IV, *Sci. Pap. Inst. Phys. Chem. Research (Tokyo)* 21, 104.

332. **O'Neill, H., Farnham, G. S. and Jackson, J. F. B.** Heat Treatment of "Standard Silver," *J. Inst. Metals* 52, 75.

333. **Orelkin, B. P.** Investigation of 1,3,5-Triphenylbenzene with X-rays, *J. Gen. Chem. (U.S.S.R.)* 3, 643.

334. **Ôsawa, A.** Equilibrium Diagram of Iron-Aluminum System, *Sci. Repts. Tôhoku Imp. Univ.* 22, 803, 823. 334a. X-ray Analysis of Iron-Aluminum Alloys II, *Kinzoku no Kenkyu* 10, 432; *Met. Abstr.* (in *Metals and Alloys*) 5, 154.

335. **Ott, E. and Slagle, F. B.** X-ray Studies of Fatty Acids and of Mixtures of Fatty Acids, *J. Phys. Chem.* 37, 257.

336. **Ott, E. and Wilson, D. A.** X-ray Studies of Very Complex Mixtures of Long-chain Compounds, *Science* 78, 16.

337. **Owen, E. A. and Iball, J.** Thermal Expansion of Zinc by the X-ray Method, *Phil. Mag.* 16, 479.

338. **Owen, E. A. and Pickup, L.** X-ray Study of Copper-Cadmium Alloys, *Proc. Roy. Soc. (London)* 139A, 526. 339. The Relation between Mean Atomic Volume and Composition in Copper-Zinc Alloys, *ibid.* 140A, 179. 340. Variation of Mean Atomic Volume with Temperature in Copper-Zinc Alloys with Observations on the β-Transformation, *ibid.* 140A, 191. 341. The Relation between Mean Atomic Volume and Composition in Silver-Zinc Alloys, *ibid.* 140A, 344.

342. **Owen, E. A. and Yates, E. L.** Precision Measurements of Crystal Parameters, *Phil. Mag.* 15, 472. 343. Crystal Parameters of Four Metals when under Reduced Pressure, *ibid.* 16, 606.

344. **Paic, M.** Research on Mercuric Sulfates with the Aid of X-rays, *Ann. chim.* 19, 427. 345. Reactions in the Solid State, *Arhiv. Hem. Farm.* 8, 114.

346. **Palacios, J., Hengstenberg, J. and de la Cueva, J. G.** Determination of Crystal Orientations with the Weissenberg X-ray Goniometer, *Anales soc. españ. fís. quím.* 31, 811.

347. **Palibin, P. A.** A Chamber for the Precise Determination of the Lattice Constants of Crystals, *J. Tech. Phys. (U.S.S.R.)* 3, 645.

348. **Pauling, L.** The Crystal Structure of Zunyite, *Z. Krist.* 84, 442. 349. The Crystal Structure of Ammonium Hydrogen Fluoride, *ibid.* 85, 380.

350. **Pauling, L. and Hultgren, R.** The Crystal Structure of Sulvanite, *Z. Krist.* 84, 204.

351. **Pauling, L. and Sherman, J.** Note on the Crystal Structure of Rubidium Nitrate, *Z. Krist.* 84, 213.

352. **Peffer, H. C., Harrison, R. L. and Shreve, R. N.** A New Synthetic Stone, *Ind. Eng. Chem.* 25, 719.

353. **Perlitz, H.** Some Conclusions from Rules on the Concentration of Valency Electrons in Binary Intermetallic Alloys, *J. Chem. Phys.* 1, 335. 354. In Which Binary Intermetallic Alloys are β-, γ- and ϵ-Lattices to be Expected? *Metallwirtschaft* 12, 103. 355. The Structure of the A-Phase of the Ag-Li System, *Z. Krist.* 86, 155.

356. **Pfarr, B.** Determination of Lattice Disturbances by X-rays, *Z. tech. Physik* 14, 220.

357. **Phillips, A. and Brick, R. M.** Grain Boundary Effects as a Factor in Heterogeneous Equilibrium of Alloy Systems, *J. Franklin Inst.* 215, 557. 358. Does the Change of Lattice Constants during the Formation of Solid Solutions Depend on Grain Size? *Metallwirtschaft* 12, 161.

359. **Pickett, L. W.** Crystal Structure of the Diphenyl Series, *Nature* 131, 513. 360. An X-ray Study of p-Diphenylbenzene, *Proc. Roy. Soc. (London)* 142A, 333.

361. **Pierce, W. C.** The Scattering of X-rays by the Gaseous Dichlorbenzenes, *Phys. Rev.* 43, 145.

362. **Posener, L.** The Dynamic Theory of X-ray Interference, *Naturwiss.* 21, 562.

Year 1933

363. **Posnjak, E. and Greig, J. W.** Notes on the X-ray Diffraction Patterns of Mullite, *J. Am. Ceram. Soc.* 16, 569.

364. **Prasad, M.** An X-ray Investigation of Crystals of Stilbene and Tolane, *Phil. Mag.* 16, 639.

365. **Prasad, M. and Kapadia, M. R.** X-ray Investigation of the Crystal Structure of p-Aminoazobenzene, *Indian J. Physics* 8, 77.

366. **Prasad, M. and Khubchandani, S. G.** An X-ray Investigation of the Crystals of Diphenylnitrosoamine, *Bull. Acad. Sci. United Provinces Agra and Oudh, Allahabad, India* 2, 129.

367. **Promisel, N.** The Application of X-rays in the Field of Electrodeposition, *Metal Ind.* (*London*) 43, 437.

368. **Randall, J. T. and Rooksby, H. P.** X-ray Diffraction and the Structure of Glasses, *J. Soc. Glass Tech.* 17, 287.

369. **Rao, S. R.** Diamagnetism of Thin Films of Bismuth, *Nature* 132, 207.

370. **de Rassenfosse, A., Mêlon, J. and Brasseur, H.** A Double Bromide of Copper and Ammonium, *Bull. Soc. roy. Sci. Liége* No. 2, 32.

371. **Regler, F.** Magnetism and Disturbances of the Crystal Lattice. X-ray Investigation of α-Iron, *Z. Physik* 82, 337. 372. Crystal Lattice Distortion and Distribution in Tensile and Fatigue Test Pieces, *Mitt. tech. Versuchsamtes* 22, 49.

373. **Reinicke, R.** Principles of X-ray Structure Results and their Possible Explanation by Tetrahedral Domains of Atomic Influence, *Z. Krist.* 84, 468. 373a. Space Representation as a Basis of Selection Principles, *Monatsh. Math. Physik* 39, 139 (1932); *Neues Jahrb. Mineral. Geol. Referate I*, 1933, 120.

374. **Reuning, E.** Varieties of Microlite from Donkerhuk, Southwest Africa, *Chem. Erde* 8, 186.

375. **Robertson, J. M.** The Crystal Structure of Anthracene. A Quantitative X-ray Investigation, *Proc. Roy. Soc.* (*London*) 140A, 79. 376. The Crystal Structure of Anthracene, *Z. Krist.* 84, 321. 377. X-ray Analysis of the Crystal Structure of Durene, *Proc. Roy. Soc.* (*London*) 141A, 594. 378. Fourier Analysis of the Durene Structure, *ibid.* 142A, 659. 379. The Crystalline Structure of Naphthalene. A Quantitative X-ray Investigation, *ibid.* 142A, 674.

380. **Robinson, B. W.** The Reflection of X-rays from Anthracene Crystals, *Proc. Roy. Soc.* (*London*) 142A, 422. 381. An Integrating Photometer for X-ray Crystal Analysis, *J. Sci. Instruments* 10, 233.

382. **Rogers, A. F.** Structural Crystallography, *Am. Mineral.* 18, 538.

383. **Rosenblatt, F. and Schleede, A.** Isomerism of the Dichlorodiamminoplatinums, *Ber.* 66B, 472; *Naturwiss.* 21, 178.

384. **Rosenhall, G.** The Dependence of the Lattice Constant on the Hydrogen Concentration in the System Palladium-Hydrogen, *Ann. Physik* 18, 150.

385. **Rossi, A.** The Crystalline Structure of $LaAl_4$ *Rendiconti accad. Lincei* 17, 182. 386. The Crystalline Structures of $LaSn_3$ and $LaPb_3$, *ibid.* 17, 839.

387. **Rossi, A. and Iandelli, A.** The Crystalline Structure of PrMg, *Rendiconti accad. Lincei* 18, 156.

388. **Royer, L.** The Orientation of Organic Crystals on Minerals with an Ionic Structure, *Compt. rend.* 196, 282.

389. **Ruff, O., Ebert, F. and Krawczynski, U.** The Ceramics of Highly Refractory Materials VII. The Binary Systems: MgO-CaO, MgO-BeO, CaO-BeO, *Z. anorg. Chem.* 213, 333.

390. **Rusterholz, A. A.** Anomalous Scattering of X-rays by Copper, *Z. Physik* 82, 538.

391. **Sakurada, I. and Hutino, K.** X-ray Investigation of Konjak Mannan, *Sci. Pap. Inst. Phys. Chem. Research* (*Tokyo*) 21, 287; *J. Soc. Chem. Ind. Japan* 36, *Suppl. binding* 90. 392. III. Orientation of the Micelle in Stretching, Thawing and Drying, *ibid.* 36, *Suppl. binding* 662. 393. X-ray Investigation of Parchment and Pergamyn, *Cellulose Ind.* (*Tokyo*) 9, 110, *Abstr.* 15. 394. Spontaneous Orientation of the Micelle in Unstretched Acetyl and Nitrocellulose Films, *J. Soc. Chem. Ind. Japan* 36, *Suppl. binding* 659. 395. X-ray Fiber Diagram of Glucomannan, *Z. physik. Chem.* 21B, 18. 395a. X-ray Investigations of Natural and Regenerated Silk, *Bull. Inst. Phys. Chem. Research* (*Tokyo*) 12, 718; *Sci. Pap. Inst. Phys. Chem. Research* (*Tokyo*) 21, 266.

396. **Sakurada, I. and Shojino, M.** The Course of Reaction in the Nitration of Cellulose, *J. Soc. Chem. Ind. Japan* 36, *Suppl. binding* 306.

Year 1933

397. **Salvia, R.** X-ray Study of Arsenical Struvite, *Anales soc. españ. fís. quím.* 31, 822.

398. **Sanders, J. P. and Cameron, F. K.** Unit Cell of Cellulose in Cotton Stalks and Cusps, *Ind. Eng. Chem.* 25, 1371.

399. **Santos, J. A. and West, C. J.** A Method of Taking X-ray Photographs of Crystalline Powders at the Temperature of Liquid Air, *J. Sci. Instruments* 10, 219.

400. **Sauerwald, F. and Teske, W.** X-ray Investigation of Fusible Metals and Alloys, *Z. anorg. Chem.* 210, 247.

401. **Sauerwald, F., Teske, W. and Lempert, G.** Multiple Systems with Iron V. X-ray Supplements for the Systems: Chromium-Carbon and Iron-Silicon-Phosphorus, *Z. anorg. Chem.* 210, 21.

402. **Sauter, E.** Evaluation of Fiber Diagrams, *Z. Krist.* 84, 453. 403. Rotation X-ray Goniometer Diagrams, *ibid.* 84, 461. 404. A Simple Universal Camera for X-ray Crystal Structure Analysis, *ibid.* 85, 156. 405. The Macro-molecular Lattice of the Polyethylene Oxides, *Z. physik. Chem.* 21B, 161. 406. A Model of the Principal Valence Chain in the Macro-molecular Lattice of Polyoxymethylene, *ibid.* 21B, 186. 407. Universal Camera and Self-indicating Rotating Crystal Camera, *ibid.* 23B, 370.

408. **Savalsberg, W.** Precipitation of Copper by Nickel Mat, *Metall u. Erz* 30, 445.

409. **Schäfer, K.** The Determination of the Atomic Factor in the Region of Anomalous Dispersion II, *Z. Physik* 86, 738.

410. **Schaller, W. T.** Ammonioborite, a New Mineral, *Am. Mineral.* 18, 480.

411. **Schenck, R. and Kortengräber, A.** The System: Manganese-Nitrogen, *Z. anorg. Chem.* 210, 273.

412. **Schiebold, E.** A New X-ray Goniometer, *Z. Krist.* 86, 370. 412a. Crystal Structure of Silicates, *Ergebnisse exakt. Naturwiss.* 12, 219.

413. **Schmid, W. E.** Apparatus for X-ray Fine-structure Analysis, *Z. physik. Chem.* 23B, 347.

414. **Schmid, E. and Siebel, G.** Mixed-crystal Formation with Single and Polycrystalline Materials, *Z. Physik* 85, 36.

415. **Schmidt, J.** The Non-existence of a Higher Nickel Carbide, *Z. anorg. Chem.* 216, 85.

416. **Schmidt, W.** Crystal Structure and Forming as Exemplified in Elektron Metal, *Z. Metallkunde* 25, 229.

417. **Schnaase, H.** Crystal Structure of Manganous Sulfide and its Mixed Crystals with Zinc Sulfide and Cadmium Sulfide, *Z. physik. Chem.* 20B, 89.

418. **Schramek, W., Neumann, H. and Schubert, C.** The X-ray Fiber Diagram as a Quantitative Measure of Changes in the Micelles of Cellulose by Chemical Processes II. The Application of Mixed Preparations to the Measurement of Partial Change in the Effect of Aqueous Sodium Hydroxide on Cellulose, *Z. physik. Chem.* 20B, 209.

419. **Schuch, E.** Transformation and Change in Properties of Gold-Copper Alloy, *Metallwirtschaft* 12, 145.

420. **Schulze, A.** Investigations on the Supposed Allotropy of Aluminum, *Metallwirtschaft* 12, 667.

421. **Schulze, G. E. R.** The Crystal Structure of BPO_4 and $BAsO_4$, *Naturwiss.* 21, 562.

422. **Schumann, H.** The Dimorphism of Lead Fluoride, *Centr. Mineral. Geol.* 1933A, 122.

423. **v. Schwarz, M. F.** Structure of Cast Iron, *Forschungsarb. Metallkunde Röntgenmetallographie* No. 10, 1.

424. **v. Schwarz, M. and Summa, O.** The Crystal Structure of Tantalum Carbide, *Metallwirtschaft* 12, 298. 425. Hardening Phenomena in Brittania Metal, *Z. Metallkunde* 25, 95.

426. **Schwiersch, H.** The Thermal Decomposition of the Natural Hydroxides of Aluminum and of Trivalent Iron. A Contribution to the Question of Reactions in the Solid State, *Chem. Erde* 8, 252.

427. **Shapiro, M. and Kurdinovskii, Y.** X-ray Investigation of the Quality of Fire-clay Brick, *Stal* 3, No. 9, 77.

428. **Shimadzu, S.** Arrangement of the Microcrystals in the Graphite Flakes Segregated from Solidifying Pig Iron, *Mem. Coll. Sci. Kyoto Imp. Univ.* 16A, 215.

Year 1933

429. Shinoda, G. X-ray Investigations on the Thermal Expansions of Solids I, *Mem. Coll. Sci. Kyoto Imp. Univ.* **16A**, 193.

430. Shonka, J. J. Effect of Temperature on the Intensity of X-rays Scattered by Powdered Sodium Fluoride, *Phys. Rev.* 43, 947.

431. Siebel, E., Berthod, R. and Koetzschenke, P. Notch-toughness and Width of Lines in Exposure of Steel to X-ray Interferences, *Arch. Eisenhüttenw.* 7, 355.

432. Sisson, W. A. Preferred Orientation Produced by Cold Rolling Low Carbon Sheet Steels, *Metals and Alloys* **4**, 193. **432a.** X-ray Analysis of Fibers I. Literature Survey. IA. Supplement to Literature Survey, *Textile Research* **3**, 242, 295; **4**, 429 (1934).

433. Sisson, W. A. and Clark, G. L. X-ray Method for Quantitative Comparison of Crystallite Orientation in Cellulose Fibers, *Ind. Eng. Chem., Anal. Ed.* **5**, 296.

434. Slagle, F. B. and Ott, E. X-ray Studies of Fatty Acids, *J. Am. Chem. Soc.* **55**, 4396, 4404.

435. Smekal, A. G. On the Theory of Real Crystals, *Phys. Rev.* **44**, 308.

436. Smith, C. S. and Lindlief, W. E. A Micrographic Study of the Decomposition of the β-Phase in the Copper-Aluminum System, *Am. Inst. Min. Met. Eng. Tech. Pub.* **No. 493.**

437. Solacolu, S. X-ray and Microscopic Examination of the Constitution of Cements, *Zement* 22, 311.

438. Southard, J. C., Milner, R. T. and Hendricks, S. B. Low-temperature Specific Heats III. Molecular Rotation in Crystalline Primary Normal Amyl Ammonium Chloride, *J. Chem. Phys.* 1, 95.

439. Spiers, F. W. Diffusion of Mercury on Rolled Tin Foils, *Phil. Mag.* **15**, 1048.

440. Šplíchal, J. Changes in the Surface and Structure of Gels and Minerals at High Temperatures, *Chim. et ind.* **Spec. No. 757.**

441. Sponsler, O. L. The Molecule in Biological Structures as Determined by X-ray Methods, *Quart. Rev. Biol.* **8**, 1.

442. v. Stackelberg, M. X-ray Crystal Structure Investigations: 1. Aluminum Carbide. 2. The Nitrides, Phosphides and Arsenides of Bivalent Metals, *Angew. Chem.* **46**, 23.

443. v. Stackelberg, M. and Paulus, R. Research on the Crystal Structure of Nitrides and Phosphides of Bivalent Metals, *Z. physik. Chem.* **22B**, 305.

444. Staub, H. Investigation of the Dielectric Properties of Seignette Salt by Means of X-rays, *Physikal. Z.* **34**, 292.

445. Staudinger, H. Macromolecular Organic Compounds. Rubber and Cellulose, *Scientia* **54**, 73.

446. Stenbeck, S. X-ray Analysis of the Alloys of Mercury with Silver, Gold and Tin, *Z. anorg. Chem.* **214**, 16.

447. Stenzel, W. and Weerts, J. Tempering Effects in Quenched Copper-Aluminum Alloys, *Metallwirtschaft* **12**, 353, 369.

448. Stephen, R. A. and Jones, W. R. D. Recovery of Steel after Fatigue Testing, *Metallurgist* (Suppl. to *Engineer* **155**) 36.

449. Stewart, G. W. Alterations in the Nature of a Fluid from a Gaseous to Liquid Crystalline Conditions as Shown by X-rays, *Trans. Faraday Soc.* **29**, 982.

450. Stillwell, C. W. The X-ray Analysis of Electrodeposited Alloys, *Metal Ind.* **31**, 47.

451. Stillwell, C. W. and Robinson, W. K. Sodium-Lead Alloys. The Structure of the Compound Known as Na_4Pb, *J. Am. Chem. Soc.* **55**, 127.

452. Stratta, R. A New Camera for Laue Spectrograms, *Ind. chim.* **8**, 986.

453. Strock, L. W. A Crystal Study of Nitropentammine Cobalti Chloride, *Bull. intern. acad. polonaise, Cl. sci. math. nat.* **1933A**, 366. **454.** The Crystallography and Space Group of Carbonato Tetrammine Cobalti Sulfate, *Z. Krist.* **86**, 42. **455.** Crystallography and X-ray Study of Carbonato Tetrammine Cobalti Perchlorate, *ibid.* **86**, 270. **456.** Magnetic Anisotropy in Crystals of trans-Dinitro Tetrammine Cobalti Chloride, *Z. physik. Chem.* **23B**, 235.

457. Sutton, T. C. Structure of Cyanuric Triazide, *Phil. Mag.* **15**, **1001.**

458. Swaryczewski, A. Guanidine d-Tartrate, Crystallographic Study, *Bull. intern. acad. polonaise, Cl. sci. math. nat.* **1933A**, 359.

459. Sykes, W. P. The Cobalt-Tungsten System, *Trans. Am. Soc. Steel Treating* **21**, 385.

460. Tabet, M. The Crystalline Structure of Thallium Fluosilicate, *Gazz. chim. ital.* **63**, **679.**

Year 1933

461. **Takané, K.** X-ray Analysis of Vesuvianite from Miho and an Ideal Formula of the Mineral, *Proc. Imp. Acad. Tokyo* 9, 9. 462. Crystal Structure of Diaspore, *ibid.* 9, 113. 463. Crystal Structure of Enargite, *ibid.* 9, 524.

464. **Tanimura, H. and Wassermann, G.** The System Copper-Beryllium, *Z. Metallkunde* 25, 179.

465. **Tarschisch, L.** X-ray Investigation of the Compounds MgZn and $MgZn_5$, *Z. Krist.* 86, 423.

466. **Taylor, W. H.** Crystal Structure of Sillimanite and Related Materials, *Trans. Ceram. Soc. (England)* 32, 7. 467. The Structure of Sanidine and Other Feldspars, *Z. Krist.* 85, 425.

468. **Taylor, W. H. and Jackson, R.** The Structure of Edingtonite, *Z. Krist.* 86, 53.

469. **Taylor, W. H., Meek, C. A. and Jackson, W. W.** The Structures of the Fibrous Zeolites, *Z. Krist.* 84, 373.

470. **Thewlis, J.** The Determination of Crystal Orientation, *Z. Krist.* 85, 74.

471. **Thiessen, P. A. and Ehrlich, E.** Discovery and Characterization of a New Type of Transformation in Alkali Salts of the Higher Fatty Acids, *Z. physik. Chem.* 165A, 453.

472. **Thomassen, L. and Wilson, J. E.** Note on the Broadening of X-ray Lines of Cold Worked Aluminum, *Phys. Rev.* 43, 763.

473. **Todd, F. C.** Changes in the X-ray Diffraction Pattern of Nitrobenzene Produced by an Electric Field, Changes in Temperature and Circulation, *Phys. Rev.* 44, 787.

474. **Trillat, J. J.** Study of the Fatty Esters of Cellulose by Means of X-rays, *Compt. rend.* 197, 1616. 475. Researches on the Change in the Lattice of Nitrocellulose, *Trans. Faraday Soc.* 29, 85.

476. **Trogus, C. and Hess, K.** Diffuse X-ray Diagrams with Cellulose Derivatives, *Z. physik. Chem.* 21B, 7.

477. **Trzebiatowski, W.** Recrystallization Effects on Synthetic Metal Bodies, *Naturwiss.* 21, 205.

478. **Tunell, G.** Determination of the Space Lattice of a Triclinic Mineral by Means of the Weissenberg X-ray Goniometer, *Am. Mineral.* 18, 181.

479. **Tunell, G., Posnjak, E. and Ksanda, C. J.** The Crystal Structure of Tenorite (Cupric Oxide), *J. Washington Acad. Sci.* 23, 195.

480. **Vargha, G. V. and Wassermann, G.** The Effect of Thickness on the Crystal Arrangement of Rolled Sheet Aluminum, *Metallwirtschaft* 12, 511. 481. Influence of Forming Process upon Preferred Orientation in Wires, *Z. Metallkunde* 25, 310.

482. **Vegard, L.** The Phosphorescence of Solid Nitrogen and its Relation to Crystal Structure, *Science* 77, 588.

483. **Verhulst, J.** The Structures of Pentachloronitrilosmate of Potassium and of Schlippe Salt, *Bull. soc. chim. Belg.* 42, 359.

484. **Volk, N. J.** Formation of Muscovite in Soils, and Refinements in Specific Gravity Separations, *Am. J. Sci.* 26, 114.

485. **Wagner, G. and Lippert, L.** Note on the Establishment of the Sodium Chloride Lattice in Cesium Chloride, *Z. physik. Chem.* 21B, 471.

486. **Wainwright, C.** X-ray Structure of Mn-rich Alloys (Quenched from Various Temps.), *J. Iron Steel Inst. Adv. copy* No. 7, *September.*

487. **Warren, B. E.** The Role of Silicon and Aluminum in Complex Silicates, *J. Am. Ceram. Soc.* 16, 412. 488. X-ray Diffraction of Vitreous Silica, *Z. Krist.* 86, 349. 489. X-ray Diffraction in Long Chain Liquids, *Phys. Rev.* 44, 969.

490. **Wassermann, G.** The Structure of Commercial Zinc Dust, *Metallwirtschaft* 12, 1.

491. **Watanabé, T.** The Crystalline Structure of Northupite and Tychite, *Sci. Pap. Inst. Phys. Chem. Research (Tokyo)* 21, 40.

492. **Weigle, J.** Precision Measurements of Rhombohedral Crystal Lattices: Sodium Nitrate, *Helv. Phys. Acta* 7, 46. 493. Measurement of a Hexagonal Crystal Lattice: Zinc, *ibid.* 7, 51.

494. **Weryha, A.** The Structure of Silver Amalgam, *Z. Krist.* 86, 335.

495. **Westgren, A.** Crystal Structure of the Carbide in High-speed Steel, *Jernkontorets Ann.* 117, 1. 496. Crystal Structure and Composition of Cubic Chromium Carbide, *ibid.* 117, 501. 497. Complex Chromium and Iron Carbides, *Nature* 132, 480.

498. **Wever, F.** X-ray Testing of Iron and Steel, *Stahl u. Eisen* 53, 497.

499. **Wever, F. and Mueller, H.** Precise Determination of Lattice Constants by

the Reflected Ray Method, *Mitt. Kaiser Wilhelm-Inst. Eisenforsch. Düsseldorf* **15**, 59.

500. **Wever, F. and Pfarr, B.** The Formation of Lattice Disturbances during Cold Deformation and their Restoration in the Recovery of the Crystals and Recrystallization, *Mitt. Kaiser Wilhelm-Inst. Eisenforsch. Düsseldorf* **15**, 137. 501. The Lattice Parameter Change of α-Iron under Hydrogen Charge, *ibid.* **15**, 147.

502. **Wiest, P.** Lattice Constant and Size of Grain of Gold-Silver Alloys, *Z. Physik* **81**, 121. 503. The Relation between the Precipitation Process in Single Crystals and Polycrystalline Materials, *Metallwirtschaft* **12**, 47. 504. Difference in Lattice Constants of Single Crystals and Polycrystalline Materials, *ibid.* **12**, 255. 505. Hardening Processes in Silver-Copper Single Crystals, *Z. Metallkunde* **25**, 238.

506. **Williams, P. S.** The Cooling of Crystals for X-ray Scattering Measurements, *Rev. Sci. Instruments* **4**, 334.

507. **Wilson, T. A.** Crystal Structure of Uranium, *Physics* **4**, 148.

508. **Wise, E. M. and Eash, J. T.** The Rôle of the Platinum Metals in Dental Alloys III. The Influence of Platinum and Palladium and Heat Treatment upon the Microstructure and Constitution of Basic Alloys, *Trans. Am. Inst. Min. Met. Eng.* **104**, *Inst. Metals Div.* 276.

509. **Wood, W. A.** The Effect of Lattice Distortion and Fine Grain on the X-ray Spectra of Metals, *Phil. Mag.* **15**, 553. 510. Lattice Distortion in Nitrided Steels and Theory of Hardness, *ibid.* **16**, 719.

511. **Wooster, N.** Note on the Structure of the Trifluorides of the Transition Metals, *Z. Krist.* **84**, 320.

512. **Wooster, W. A.** Electrometer Triode in the X-ray Ionization Spectrometer, *Nature* **131**, 545.

513. **Wooster, W. A. and Wooster, N.** A Graphical Method of Interpreting Weissenberg Photographs, *Z. Krist.* **84**, 327.

514. **Wyart, J.** Research on the Zeolites, Thesis Presented to the Faculty of Sciences, Univ. Paris, *Bull. soc. franç. mineral.* **56**, 81.

515. **Wyckoff, R. W. G.** Discussion on the Physical Chemistry of the Alumina-Silica Refractories, *J. Am. Ceram. Soc.* **16**, 422.

516. **Yap, C.-P.** A Critical Study of Some Iron-rich Iron-Silicon Alloys, *J. Phys. Chem.* **37**, 951.

517. **Zachariasen, W. H.** X-ray Examination of Colusite, *Am. Mineral.* **18**, 534. 518. The Crystal Lattice of Sodium Bicarbonate, *J. Chem. Phys.* **1**, 634. 519. Calculation of the Refractive Indices of Sodium Bicarbonate from the Atomic Arrangement, *ibid.* **1**, 640.

520. **Zechmeister, L., Mark, H. and Tóth, G.** Cellotriose and its Significance for the Structure of Cellulose, *Ber.* **66B**, 269.

521. **Zedlitz, O.** Lime-Iron Garnets Rich in Titanium, *Centr. Mineral. Geol.* **1933A**, 225. 522. Partschinite, *ibid.* **1933A**, 297.

523. **Zintl, E. and Brauer, G.** Metals and Alloys X. The Valence Electron Rule and the Atomic Radius of Non-noble Metals in Alloys, *Z. physik. Chem.* **20B**, 245.

524. **Zintl, E. and Husemann, E.** Metals and Alloys XII. Binding Type and Lattice Structure of Magnesium Compounds, *Z. physik. Chem.* **21B**, 138.

525. **Zintl, E. and Kaiser, H.** Metals and Alloys VI. Ability of Elements to Form Negative Ions, *Z. anorg. Chem.* **211**, 113.

526. **Zintl, E. and Neumayr, S.** Metals and Alloys XI. Lattice Structure of NaIn and the Deformation of Atoms in Alloys, *Z. physik. Chem.* **20B**, 272. 527. VII. Lattice Structure of Indium, *Z. Elektrochem.* **39**, 81. 528. VIII. Crystal Structure of β-Lanthanum, *ibid.* **39**, 84. 529. IX. Alloy Phases of the Type $NaPb_3$ *ibid.* **39**, 86.

530. **Zwicky, F.** The Structure of Real Crystals, *Helv. Phys. Acta* **6**, 210. **530a.** The Structure of Real Crystals, *ibid.* **7**, 294. 531. The Problem of the Solid State of Matter, *Mech. Eng.* **55**, 427.

532. **Correns, C. W.** The Constituents of Clays, *Z. deut. geol. Ges.* **85**, 706.

533. **Fukushima, E.** The Effects of the Mechanical Strain on the Intensity of X-rays Reflected by a Crystal, *J. Sci. Hiroshima Univ.* **3A**, 177.

534. **Galitelli, P.** Calcium Sulfate Hemihydrate and Soluble Anhydrite, *Per. mineral.* **4**, 132; *Neues Jahrb. Mineral. Geol. Referate I*, **1933**, 472.

535. **Galitelli, P. and Büssem, W.** Calcium Sulfate Hemihydrate and Soluble Anhydrite, *Per. mineral.* **4**, 1.

536. **Heesch, H. and Laves, F.** Thin Packing of Spheres, *Z. Krist.* **85**, 443.

Year 1933

537. **Kawakami, M.** The Equilibrium Diagram of Al-Mg System, *Kinzoku no Kenkyu* 10, 532; *Met. Abstr.* (in *Metals and Alloys*) 5, 217.

538. **Konobejewski, S.** Precision Methods for X-ray Examination of Metals, *Zavodskaya Lab.* 1933, No. 6, 23.

539. **Korn, D.** The Structure Relations of Opaque Ores and Metals under the Microscope, *Neues Jahrb. Mineral. Geol., Beilage-Bd.* 67A, 428.

540. **Nishikawa, S., Sakisaka, Y. and Sumoto, I.** An X-ray Examination of the Harmonic Thickness Vibration of Piezoelectric Quartz Plates, *Phys. Rev.* 43, 363.

541. **Noble, W. N.** X-ray Study of Action of Mill Additions in Fired Ground-coat Enamels, *Better Enameling* 4, 8; *Ceram. Abstr.* (in *J. Am. Ceram. Soc.*) 12, 413. 542. X-rays for the Study of Porcelain Enamels, *Better Enameling* 4, 18; *Ceram. Abstr.* (in *J. Am. Ceram. Soc.*) 12, 413.

543. **Del Nunzio, B.** Crystal Lattice of Nickel and the Sudden Change in Magnetic Properties, *Atti ist. Veneto* 92, 541.

544. **Orowan, E.** The Structure of Real Crystals, *Helv. Phys. Acta* 7, 285.

545. **Schilly, W.** The Relations among Morphology, Structure and Genesis in Celestite, *Neues Jahrb. Mineral. Geol., Beilage-Bd.* 67A, 323.

546. **Zhdanov, G. S. and Iveronova, V. I.** The Recrystallization Texture of Duralumin, *J. Exptl. Theoret. Phys.* (*U.S.S.R.*) 3, 579.

Year 1934

1. **Ageev, N. and Shoiket, D.** The Nature of Solid Solutions of Aluminum in Silver, *Metallurgia* 9, 38.

2. **Anderson, E. A., Fuller, M. L., Wilcox, R. L. and Rodda, J. L.** The High-Zinc Region of the Copper-Zinc Phase-equilibrium Diagram, *Am. Inst. Min. Met. Eng., Inst. Metals Div., Tech. Pub.* No. 571.

3. **Andress, K. R. and Carpenter, C.** Crystal Hydrates II. The Structures of Chromium Chloride and Aluminum Chloride Hexahydrates, *Z. Krist.* 87, 446.

4. **Andress, K. R. and Gundermann, J.** Crystal Hydrates I. The Structures of Magnesium Chloride and Magnesium Bromide Hexahydrates, *Z. Krist.* 87, 345.

5. **Aoyama, S. and Fukuroi, T.** On the Absorption Spectrum of X-rays, *Sci. Repts. Tôhoku Imp. Univ.* 23, 405.

6. **Astbury, W. T. and Lomax, R.** X-ray Photographs of Crystalline Pepsin, *Nature* 133, 795.

7. **Astbury, W. T. and Preston, R. D.** A Mercury-sealed Water-cooled Rotating X-ray Target, *Nature* 133, 460.

8. **Bancroft, W. D., Calkin, J. B. and Stillwell, C. W.** Effect on the X-ray Pattern of Drying Caustic Pretreated Cotton, *Textile Research* 4, 411.

9. **Bannister, F. A.** The Crystal Structure and Optical Properties of Matlockite, *Mineralog. Mag.* 23, 587.

10. **Barasoain, J. A. and Salvia, R.** Photographic Means of Reflection of X-rays XII. Comparison of Photographic and Ionization Methods, *Anales soc. españ. fís. quím.* 32, 53.

11. **Baroni, A.** Cadmium-Lithium Alloys, *Z. Elektrochem.* 40, 565.

12. **Barsha, J. and Hibbert, H.** Reactions Relating to Carbohydrates and Polysaccharides XLVI. Structure of the Cellulose Synthesized by the Action of *Acetobacter xylinus* on Fructose and Glycerol, *Can. J. Research* 10, 170.

13. **Barth, T. F. W.** Polymorphic Phenomena and Crystal Structure, *Am. J. Sci.* 27, 273.

14. **Barth, T. F. W. and Posnjak, E.** The Crystal Structure of Ilmenite, *Z. Krist.* 88, 265.

15. **Beevers, C. A. and Lipson, H.** Crystal Structure of Copper Sulfate, *Nature* 133, 215. 15a. The Crystal Structure of Copper Sulfate Pentahydrate, *Proc. Roy. Soc.* (*London*) 146A, 570.

16. **Bernal, J. D.** Discussion on Heavy Hydrogen, *Proc. Roy. Soc.* (*London*) 144A, 24.

17. **Bernal, J. D. and Crowfoot, D.** X-ray Photographs of Crystalline Pepsin, *Nature* 133, 794. 18. X-ray Crystallographic Measurements on Some Derivatives of Cardiac Aglucones, *J. Soc. Chem. Ind.* 53, *Chem. Ind.* 953.

19. **Bernal, J. D., Crowfoot, D., Robinson, B. W. and Wooster, W. A.** Crystallography (1932-1933), *Ann Repts. Chem. Soc. for 1933,* 30, 360.

20. **Binder, O.** Interaction of Aqueous Solution of Cupric Sulfate and Cupric Hydroxide, *Compt. rend.* 198, 653.

Year 1934

21. **Blake, F. C.** Calculation of Intensity Factors for the Powder Method of X-ray Crystal Analysis, *J. Chem. Physics* 2, 320.

22. **Blewett, J. P.** Two Variations of the Powder Method of X-ray Analysis of Crystals, *J. Sci. Instruments* 11, 148.

23. **Borelius, G.** Theory of Transitions of Metallic Mixed Phases, *Ann. Physik* 20, 57.

24. **Boyd, J. E.** Scattering of X-rays by Cold Worked and by Annealed Beryllium, *Phys. Rev.* 45, 832.

25. **Bozorth, R. M. and Haworth, F. E.** The Perfection of Quartz and Other Crystals and its Relation to Surface Treatment, *Phys. Rev.* 45, 821.

26. **Bradley, A. J. and Rodgers, J. W.** The Crystal Structure of the Heusler Alloys, *Proc. Roy. Soc.* (*London*) 144A, 340.

27. **Braekken, H., Koren, C. J. and Sörensen, N. A.** X-ray Investigation of Some Sugars and Sugar Derivatives I, *Z. Krist.* 88, 205.

28. **Bragg, W. H.** Structure of the Azide Group, *Nature* 134, 138. 29. Molecule Planning, *Trans. Faraday Soc.* 30, 665.

30. **Bragg, W. L.** The Exploration of the Mineral World by X-rays, *Brit. Ass'n. Adv. Sci., Aberdeen, Sept. 10.*

31. **Bragg, W. L. and Williams, E. J.** The Effect of Thermal Agitation on Atomic Arrangement in Alloys, *Proc. Roy. Soc.* (*London*) 145A, 699.

32. **Brasseur, H., de Rassenfosse, A. and Piérard, J.** Crystallographic Investigations of the Double Cyanides IV. Crystallographic Study of Barium Nickel Cyanide, *Z. Krist.* 88, 210. 33. Crystallographic Study of Barium Nickelocyanide, *Compt. rend.* 198, 1048; *Bull. soc. roy. sci. Liége,* No. 2, 31.

34. **Brill, R.** The Lattice Constants of α-Fe_2O_3, *Z. Krist.* 88, 177.

35. **Buerger, M. J.** The Weissenberg Reciprocal Lattice Projection and the Technique of Interpreting Weissenberg Photographs, *Z. Krist.* 88, 356. 36. The Temperature-structure-composition Behavior of Certain Crystals, *Proc. Natl. Acad. Sci.* 20, 444. 36a. The Non-Existence of a Regular Secondary Structure in Crystals, *Z. Krist.* 89, 242.

37. **Büssem, W. and Gross, F.** Structure and Gas Content of Nickel Layers Obtained by Cathode Sputtering, *Z. Physik* 87, 778.

38. **Büssem, W., Günther, P. and Tubin, R.** The Structure of Thallium and Potassium Thiocyanates, *Z. physik. Chem.* 24B, 1.

39. **Bugakow, W., Isaitschew, I. and Kurdjumow, G.** Transformation in the Copper-Tin Eutectoid Alloys II. Changes in Properties of Quenched Alloys on Annealing, *Physik. Z. Sowjetunion* 5, 22.

40. **Bumm, H. and Dehlinger, U.** The Constitutional Diagram Gold-Manganese, *Metallwirtschaft* 13, 23.

41. **Burgers, W. G.** The Process of Transition of the Cubic Body-centered Modification into the Hexagonal Close-packed Modification of Zirconium, *Physica* 1, 561.

42. **Burgers, W. G. and Basart, J. C. M.** Formation of High-melting Metallic Carbides by Igniting a Carbon Filament in the Vapor of a Volatile Halogen Compound of the Metal, *Z. anorg. Chem.* 216, 209. 43. Preparation of Ductile Tantalum by Thermal Dissociation of $TaCl_5$, *ibid.* 216, 223.

44. **Burns, J. L.** Classification of α-Iron-Nitrogen and α-Iron-Carbon as Age-hardening Alloys, *Am. Inst. Min. Met. Eng., Tech. Pub.* No. 556.

45. **Cabicar, F.** Use of X-rays for the Determination of the Particle Size, *Chem. Obzor* 9, 91, 108.

46. **Caspari, W. A.** Calcium Sulfate Hemihydrate, *Nature* 133, 648.

47. **Chalenko, I. I.** X-ray Photography of Liquids II. Diffraction of X-rays in Mixtures of Allyl Mustard Oil and Methylaniline, *Ukrainskii Khem. Zhur.* 8, *Tech. Part* 140.

48. **Chrobak, L.** Quantitative Spectrometric Studies of Ammonium and of Potassium Cupric Chloride Dihydrate, *Z. Krist.* 88, 35.

49. **de la Cierva, P. and Palacios, J.** Photometric Measurement of Reflection of X-rays III. The Atomic Factors of Sulfur and Lead, *Anales soc. españ. fís. quím.* 32, 391.

50. **Clark, G. L., Flege, R. K. and Ziegler, P. F.** Surgical Catgut Ligatures. X-ray Diffraction Studies, *Ind. Eng. Chem.* 26, 440.

51. **Clark, G. L., Howe, E. E. and Badger, A. E.** Lattice Dimensions of Some Solid Solutions in the System MgO-Al_2O_3, *J. Am. Ceram. Soc.* 17, 7.

Year 1934

52. **Clark, G. L. and Mrgudich, J. N.** An X-ray Diffraction Study of the Effect of Rachitis upon the Structural Characteristics of Bone, *Am. J. Physiol.* 108, 74.

53. **Clark, G. L. and Southard, J.** Sorption on Cotton Fibers of Dyes with Varying Molecular Association in Solution, *Physics* 5, 95.

54. **Clark, G. L., Warren, W. J. and Smith, W. H.** X-ray Diffraction Studies of the Bureau of Standards Rubber Fractions, *Science* 79, 433.

55. **Clark, G. L. and Werner, C. O.** The Crystal Structure of the Silver Nitrate-Urea Addition Compound I. Space Group and Molecular Association, *Z. Krist.* 88, 162.

56. **Clarkson, C. E. and Malkin, T.** Alternation in Long-chain Compounds II. An X-ray and Thermal Investigation of the Triglycerides, *J. Chem. Soc.* 1934, 666.

57. **Corey, R. B.** The Crystal Structure of Tetramethyl Ammonium Fluosilicate, *Z. Krist.* 89, 10.

58. **Corey, R. B. and Pestrecov, K.** The Space Group of Silver Nitrate Diammoniate, *Z. Krist.* 89, 528.

59. **Corey, R. B. and Wyckoff, R. W. G.** The Crystal Structure of Silver Sulfate Tetrammoniate, *Z. Krist.* 87, 264. 60. The Crystal Structure of Dimethyl Ammonium Chlorostannate, *ibid.* 89, 469.

61. **Cox, E. G., Saenger, H. and Wardlaw, W.** Structure of the Thio-Ether Compounds of Platinous and Palladous Chlorides, *J. Chem. Soc.* 1934, 182.

62. **Dankov, P. D.** The Physics of the Phenomenon of Catalysis. Structure and Genesis of Catalysts, *Uspekhi Fiz. Nauk* 14, 63.

63. **Dankov, P. D. and Kochetkov, A. A.** Limiting Dimensions of Catalyst Particles, *Compt. rend. acad. sci. (U.R.S.S.)* 2, 359.

64. **Davey, W. P.** "A Study of Crystal Structure and its Applications," New York (1934).

65. **Davuidov, G. V.** X-ray Investigation of the Transition of Austenite to Martensite during the Working Process, *J. Tech. Phys.* (*U.S.S.R.*) 4, 544.

66. **Dehlinger, U.** Continuous Transition and Critical Point for Two Solid Phases, *Z. physik. Chem.* 26B, 343. 67. Kinetics and Constitutional Diagram for the Irreversible Transformation in the System Iron-Nickel, *Z. Metallkunde* 26, 112. 68. The Effect of X-ray Examination on the Development of Metallurgy, *Arch. Eisenhüttenw.* 7, 523.

69. **Derksen, J. C. and Katz, J. R.** Intramicellar Swelling of Graphitic Acid I. Isotherm. Effect of Lyotropic Substances, of Temperature and of pH, *Rec. trav. chim.* 53, 652.

70. **Dhar, J.** X-ray Analysis of the Crystal Structure of Bibenzyl, *Current Sci.* 2, 480; *Indian J. Physics* 9, 1.

71. **Dickinson, B. N.** The Crystal Structure of Tetramminopalladous Chloride, *Z. Krist.* 88, 281.

72. **Dupré la Tour, F. and Riedberger, A.** Effect of Temperature on Crystal Mesh of Some Normal, Dibasic Fatty Acids, *Compt. rend.* 199, 215.

73. **Dwyer, F. P. J. and Mellor, D. P.** X-ray Diffraction Studies of the Crystallization of Amorphous Silica, *J. Proc. Roy. Soc. N. S. Wales* 67, 420. **73a.** An X-ray Study of Opals, *ibid.* 68, 47.

74. **Ebert, F. and Flasch, H.** X-ray Determination of New Forms of Combination I. The Tungsten Oxides W_4O_{11} and W_8O_{23}, *Z. anorg. Chem.* 217, 95.

75. **Ebert, F. and Hartmann, H.** Nomenclature, *Z. anorg. Chem.* 217, 156. (See 1934, 187).

76. **Ehret, W. F. and Abramson, M. B.** The Nature of the Solid Phase in the System Antimony-Bismuth, *J. Am. Chem. Soc.* 56, 385.

77. **Ellefson, B. S. and Taylor, N. W.** Crystal Structures and Expansion Anomalies of MnO, MnS, FeO, Fe_3O_4 between 100° K and 200° K, *J. Chem. Physics* 2, 58.

78. **Elliott, N.** The Crystal Structure and Magnetic Susceptibility of Cesium Argentous Auric Chloride and Cesium Aurous Auric Chloride, *J. Chem. Physics* 2, 419.

79. **Frenzel, A. and Hofmann, U.** A Graphite-Sulfuric Acid Compound (Graphite Bisulfate), *Z. Elektrochem.* 40, 511.

80. **Fuller, M. L. and Edmunds, G.** Crystal Orientations Developed by Progressive Cold-rolling of an Alloyed Zinc, *Am. Inst. Min. Met. Eng., Inst. Metals Div., Tech. Pub.* No. 524.

Year 1934

81. **Gingrich, N. S. and Warren, B. E.** The Interpretation of X-ray Diffraction Patterns of a Fluid at Various Densities, *Phys. Rev.* 46, 248.

82. **Goetz, A., Buchta, J. W. and Ho, T. L.** Thermal Expansions of Alloyed Bi Crystals in the Region of the Eutectic Melting Point, *Phys. Rev.* 46, 538.

83. **Goldschmidt, V. M.** Crystal Chemistry, *Handwörterbuch d. Naturwiss.* 5, *2nd Ed.* p. 1.

84. **Goldsztaub, S.** Crystal Structure of Ferric Oxychloride, *Compt. rend.* 198, 667.

85. **Gorsky, W. S.** The Crystal Structure of Yellow HgI_2, *Physik. Z. Sowjetunion* 5, 367. 85a. Transitions in the Copper-Gold Alloy II. The Migration of Atoms in the Lattice of Copper-Gold. III. The Effect of Strain on the Equilibrium in the Ordered Lattice of Copper-Gold, *ibid.* 6, 69, 77.

86. **Gossner, B. and Besslein, J.** Crystallographic Relations between Silicates and Phosphates. Beryllonite, *Centr. Mineral. Geol.* 1934A, 144.

87. **Gossner, B. and Kraus, O.** The Crystal Lattice of Ammonium Hexafluorosilicate, *Z. Krist.* 88, 223. 88. The Crystal Lattice of Telluric Acid, *ibid.* 88, 298. 89. The Crystal Form and Chemical Composition of Polybasite, *Centr. Mineral. Geol.* 1934A, 1. 90. The Wöhlerite and Mosandrite Groups, *ibid.* 1934A, 72.

91. **Gossner, B. and Reindl, E.** The Chemical Composition of Titanium-bearing Silicates, Especially of Astrophyllite, *Centr. Mineral. Geol.* 1934A, 161.

92. **Gough, H. J.** Crystalline Structure in Relation to Failure of Metals, Especially by Fatigue, *Proc. Am. Soc. Testing Materials* 33, *Pt.* 2, 3.

93. **Graf, L.** X-ray Investigation of Calcium at High Temperatures II, *Physikal. Z.* 35, 551.

94. **Grigoriev, D. P.** The Preparation of Artificial Magnesian Mica, *Centr. Mineral. Geol.* 1934A, 219.

95. **Grime, H. and Santos, J. A.** The Structure and Color of Anhydrous Cobalt Chloride at Room and Very Low Temperatures, *Z. Krist.* 88, 136.

96. **Gruner, J. W.** The Crystal Structures of Talc and Pyrophyllite, *Z. Krist.* 88, 412.

97. **Hägg, G.** Powder Photographs of a New Iron Carbide, *Z. Krist.* 89, 92. 98. X-ray Investigations on the Constitution and Decomposition of Martensite, *Jernkontorets Ann.* 118, 173.

99. **Halla, F., Tompa, H. and Zimmermann, L.** Thallium Oxides (and Lead Suboxide), *Z. Krist.* 87, 184.

100. **Hammel, F.** X-ray Spectra of Manganous Sulfate and its Hydrates, *Compt. rend.* 199, 282.

101. **v. Hámos, L.** X-ray Photography by Means of Curved Crystal Reflectors II, *Ann. Physik* 19, 252.

102. **Harris, S.** On the Possibility of a Secondary Structure in Calcite, *Phys. Rev.* 45, 646.

103. **Hartmann, H., Fröhlich, H. J. and Ebert, F.** A New Pernitride of Strontium and Calcium; Imides of the Alkaline Earth Metals, *Z. anorg. Chem.* 218, 181.

104. **Hartree, D. R.** Results of Calculations of Atomic Wave Functions II. Results for K^+ and Cs^+, *Proc. Roy. Soc. (London)* 143A, 506.

105. **Hermann, C.** Tensors and Crystal Symmetry, *Z. Krist.* 89, 32.

106. **Hess, K.** Morphology and Chemistry of Organic High-molecular Natural Substances, *Naturwiss.* 22, 469.

107. **Heusler, O.** Crystal Structure and Ferromagnetism of Copper-Manganese-Aluminum Alloys, *Ann. Physik* 19, 155.

108. **Hey, M. H. and Bannister, F. A.** Studies on the Zeolites VI. Edingtonite, *Mineralog. Mag.* 23, 483.

109. **Hoard, J. L. and Grenko, J. D.** The Crystal Structure of Potassium Osmyl Chloride, *Z. Krist.* 87, 100. 110. The Crystal Structure of Cadmium Hydroxychloride, *ibid.* 87, 110.

111. **Hocart, R.** Contribution to the Study of Some Optically Anomalous Crystals, *Bull. soc. franç. mineral.* 57, 5.

112. **Hoffmann, A.** Oxygen Acids of Quadrivalent Cerium and Thorium, *Naturwiss.* 22, 206.

113. **Hofmann, U., Endell, K. and Wilm, D.** X-ray and Colloid-chemical Investigations on Clay, *Angew. Chem.* 47, 539.

114. **Hultgren, R.** The Crystal Structure of Ammonium Beryllium Fluoride, *Z. Krist.* 88, 233.

Year 1934

115. **Hulubei, H.** Focusing Methods in the Analysis of Crystalline Powders, *Compt. rend.* 198, 79. 116. Focusing Methods in the Analysis of Crystalline Powders and the Spectrography of X- and γ-rays, *ibid.* 198, 2164.

117. **Iball, J.** X-ray Analysis of the Structure of Chrysene, *Proc. Roy. Soc. (London)* 146A, 140.

118. **Isaitschew, I. and Kurdjumow, G.** Transformations in the Copper-Tin Eutectoid Alloys I. The Phases Resulting from the Decomposition of the β-Phase during Annealing and their Orientation, *Physik. Z. Sowjetunion* 5, 6.

119. **Ito, T.** The Structure of Epididymite, *Z. Krist.* 88, 142.

120. **Jay, A. H.** The Thermal Expansion of Bismuth by X-ray Measurements, *Proc. Roy. Soc. (London)* 143A, 465. 121. The Estimation of Small Differences in X-ray Wave Lengths by the Powder Method, *Proc. Phys. Soc. London* 46, 713. 121a. The Thermal Expansion of Silver, Quartz and Bismuth by X-ray Measurements, *Z. Krist.* 89, 282.

122. **Jesse, W. P.** X-ray Crystal Measurements of Nickel at High Temperatures, *Physics* 5, 147.

123. **Jette, E. R.** Intermetallic Solid Solutions, *Am. Inst. Min. Met. Eng., Inst. Metals Div., Tech. Pub.* No. 560.

124. **Jette, E. R., Bruner, W. L. and Foote, F.** An X-ray Study of the Gold-Iron Alloys, *Am. Inst. Min. Met. Eng., Inst. Metals Div., Tech. Pub.* No. 526.

125. **Jette, E. R., Nordstrom, V. H., Queneau, B. and Foote, F.** X-ray Studies on the Nickel-Chromium System, *Am. Inst. Min. Met. Eng., Inst. Metals Div., Tech. Pub.* No. 522.

126. **Jones, H.** The Theory of Alloys in the γ-Phase, *Proc. Roy. Soc. (London)* 144A, 225.

127. **Kast, W.** Liquid Crystals, X-ray and Optical Investigations of the Anisotropic and Isotropic Melts of p-Azoxyanisole, *Ann. Physik* 19, 571.

127a. **Katz, J. R.** "Die Röntgenspektrographie als Untersuchungsmethode," Berlin (1934).

128. **Kawano, Y.** Chemical Formula of Basaltic Hornblende, *Proc. Imp. Acad. Tokyo* 10, 349.

129. **Kaye, G. W. C.** Grain Size and Distortion in Electrodeposited Metals, *Natl. Phys. Lab. Rept. (London)* 1933, 42.

130. **Keesom, W. H. and Köhler, J. W. L.** New Determination of the Lattice Constant of Carbon Dioxide, *Physica* 1, 167. 130a. The Lattice Constant and Expansion Coefficient of Solid Carbon Dioxide, *ibid.* 1, 655.

131. **Keggin, J. F.** Structure and Formula of 12-Phosphotungstic Acid, *Proc. Roy. Soc. (London)* 144A, 75.

132. **Ketelaar, J. A. A.** Crystal Structure of the Low-temperature Modification of Ammonium Bromide, *Nature* 134, 250. 133. The Crystal Structure of the High-temperature Modifications of Ag_2HgI_4 and Cu_2HgI_4, *Z. Krist.* 87, 436. 134. The Crystal Structure of Nickel Bromide and Iodide, *ibid.* 88, 26.

135. **Klemm, W. and Frischmuth, G.** The System Germanium-Tellurium, *Z. anorg. Chem.* 218, 249.

136. **Klug, H. P.** The X-ray Study of Red Monoclinic Selenium. Proof of the Existence of Two Red Monoclinic Varieties of Selenium, *Z. Krist.* 88, 128.

137. **Koester, W. and Schmidt, W.** Relation between Lattice Parameter and Ferromagnetism, *Arch. Eisenhüttenw.* 8, 25.

138. **Kohlschütter, H. W.** Chemistry of Solid Surfaces I. Adsorption of Gas by Pseudomorphous and Amorphous Ferric Oxide, *Z. physik. Chem.* 170A, 20.

139. **Kokubo, S.** On the Nature of the Solid Solution of Aluminum in Silver, *Sci. Repts. Tôhoku Imp. Univ.* 23, 45.

140. **Kolkmeijer, N. H. and Favejee, J. C. L.** The Structure of the Water Envelope of Starch Micelles, *Z. Krist.* 88, 226.

141. **Kolkmeijer, N. H. and van Hengel, J. W. A.** Cubic and Hexagonal Silver Iodide, *Z. Krist.* 88, 317.

142. **Kolkmeijer, N. H. and Heyn, A. N. J.** The Hydration Film of Cellulose in Cell Walls, *Proc. Acad. Sci. Amsterdam* 37, 92.

143. **Komar, A. and Obukhoff, V.** Multiple Laue Spots from Aluminum Crystals, *Nature* 133, 687; *Phys. Rev.* 45, 646.

144. **Kôzu, S. and Kani, K.** Thermal Expansion of Aragonite and its Atomic Displacements by Transformation into Calcite between 450° C and 490° C in Air I, II, *Proc. Imp. Acad. Tokyo* 10, 222, 271.

Year 1934

145. **Kramer, J.** Non-conducting Modifications of Metals, *Ann. Physik* 19, 37.

146. **Krasnikov, A. I.** An X-ray Tube of Increased Power, *J. Exptl. Theoret. Phys.* (*U.S.S.R.*) 4, 171. 147. An X-ray Tube with a Cylindrical Anticathode, *ibid.* 4, 178.

148. **Kühlewein, H.** Properties of Ferromagnetic Alloys of the Ternary System Iron-Nickel-Vanadium, *Z. anorg. Chem.* 218, 65.

149. **Kunzl, V. and Köppel, J.** New Method for Determining Grating Constants of Crystals, *J. phys. radium* 5, 145.

150. **Laudermilk, J. D. and Woodford, A. O.** Secondary Montmorillonite in a California Pegmatite, *Am. Mineral.* 19, 260.

151. **Leuck, G. J. and Mark, H.** An X-ray Examination of the Acetates of Glucose, Cellobiose and Cellotriose, *J. Am. Chem. Soc.* 56, 1959.

152. **Levi, G. R. and Tabet, M.** Examination of Electrolytic Silver Deposits by X-rays, *Rendiconti accad. Lincei* 18, 463. 153. Fibrous Structure in Ionic Lattices II, *ibid.* 19, 723.

154. **Lihl, F.** The Influence of the Divergence of the Primary X-ray Beam on the Evaluation of Diagrams Obtained by the Back-reflection Methods, *Ann. Physik* 19, 305. 155. Alteration in the Elemental Cell by Directed Forces, *Physikal. Z.* 35, 460.

156. **Long, J. H., Frazer, J. C. W. and Ott, E.** The Activity and Crystal Structures of Mixed Metal Catalysts, *J. Am. Chem. Soc.* 56, 1101.

157. **Lonsdale, K.** Crystal Structure of 1-3-5 Triphenylbenzene, *Nature* 133, 67.

158. **Ludwik, P. and Scheu, R.** Danger of Fracture and X-ray Diffraction, *Metallwirtschaft* 13, 257.

159. **Lüdke, W.** Identification of Synthetic Hornblendes by X-ray Diagram, *Naturwiss.* 22, 452.

160. **Luyken, W. and Kraeber, L.** The Behavior of Siderite during Roasting, *Stahl u. Eisen* 54, 361.

161. **McMurchy, R. C.** The Crystal Structure of the Chlorite Minerals, *Z. Krist.* 88, 420.

162. **Machatschki, F.** The Crystal Structure of Haüynite and Noselite, *Centr. Mineral. Geol.* 1934A, 136.

163. **Mackinney, G.** Crystal Structure of Carotenoids, *J. Am. Chem. Soc.* 56, 488.

164. **Mark, H.** The Space Diagram of Organic Molecules and Molecular Aggregates, *Z. Elektrochem.* 40, 413.

165. **Matano, C.** X-ray Studies on the Diffusion of Metals in Copper, *Japan. J. Physics* 9, 41.

166. **Mathieu, M.** Structure of Cellulose and its Derivatives, *Compt. rend.* 198, 1434. 167. X-ray Examination of Fixation of Acetone by Cellulose Nitrate, *ibid.* 199, 55.

168. **Matsumoto, N.** The Distance between the Micelles in Viscose Rayon, *J. Soc. Chem. Ind. Japan* 37, *Suppl. binding* 356.

169. **Mayo, E. B. and O'Leary, W. J.** Oligonite, a Manganosiderite from Leadville, Colorado, *Am. Mineral.* 19, 304.

170. **Megaw, H. D.** The Crystal Structure of Hydrargillite, *Z. Krist.* 87, 185.

171. **Mehmel, M.** Fine-structure Investigation of Boracite, *Z. Krist.* 88, 1.

172. **Mehmel, M. and Nespital, W.** Crystallographic and X-ray Investigation of Potassium Lead Chloride, *Z. Krist.* 88, 345.

173. **Meisel, K.** The Crystal Structure of FeP_2, *Z. anorg. Chem.* 218, 360. 174. The Lattice Constant of OsS_2, *ibid.* 219, 141.

175. **Meyer, K. H. and Go, Y.** Stretched Plastic Sulfur and its Structure, *Helv. Chim. Acta* 17, 1081.

176. **Michel, A. and Chaudron, G.** Transformations of Pyrrhotite and Ferrous Sulfide, *Compt. rend.* 198, 1913.

177. **Milligan, W. O.** The Color and Crystal Structure of Precipitated Cadmium Sulfide, *J. Phys. Chem.* 38, 797.

178. **Moeller, H. and Barbers, J.** X-ray Measurements of Elastic Tensions, *Mitt. Kaiser Wilhelm-Inst. Eisenforsch. Düsseldorf* 16, 21.

179. **Morral, F. R. and Westgren, A.** The Crystal Structure of a Complex Copper-Silicon Compound, *Arkiv. Kemi Mineral. Geol.* 11B, No. 37. 180. Crystal Structure of Tl_7Sb_2, *Svensk Kem. Tids.* 46, 153.

181. **Mundt, H.** X-ray Investigation of Hydrogen-charged Palladium-Gold Alloys, *Ann. Physik* 19, 721.

Year 1934

182. **Murdock, C. C.** Multiple Laue Spots, *Phys. Rev.* 45, 117.

183. **Nähring, E.** The Shortening of Illumination Time in X-ray Structure Exposures by Application of Reflection Diaphragms, *Z. tech. Physik* 15, 151.

184. **Nagelschmidt, G.** X-ray Investigation of Clays I. X-ray Diagrams of Some Clay Minerals. II. Mineral Composition of Clay from Malliss, *Z. Krist.* 87, 120.

185. **Nahmias, M. E. and Hägg, G.** Bauxite and Mullite, Studied by Means of X-rays, *Z. Krist.* 88, 90.

186. **Nakai, T. and Fukami, Y.** On Change of Inner Structure of Siliceous Materials by Heat Treatment I. X-ray Study of Natural Minerals, *J. Soc. Chem. Ind. Japan* 37, *Suppl. binding* 283.

187. **Neuburger, M. C.** Precision Measurement of the Lattice Constants of Body-centered Cubic β-Tungsten, *Z. anorg. Chem.* 217, 154.

188. **Noda, T.** Crystals of Calcium Carbonate II. Mechanism of the Formation of Calcium Carbonate Crystals, *J. Soc. Chem. Ind. Japan* 37, *Suppl. binding* 320.

189. **Noll, W.** Hydrothermal Synthesis of Kaolin, *Mineralog. petrog. Mitt.* 45, 175.

190. **Norton, J. T.** X-ray Study of the Action of Aluminum during Nitride Hardening, *Am. Inst. Min. Met. Eng. Tech. Pub.* No. 550.

191. **O'Daniel, H.** Long Wave X-rays for the Solution of Special Crystal Structure Questions, *Z. Krist.* 88, 304.

192. **Ölander, A.** An Electrochemical and X-ray Study of Solid Thallium-Lead Alloys, *Z. physik. Chem.* 168A, 274. 193. Crystal Structure of Thallium-Bismuth Alloys, *Z. Krist.* 89, 89.

194. **Orelkin, B. and Lonsdale, K.** The Structure of Symm. (1-3-5) Triphenylbenzene I, *Proc. Roy. Soc. (London)* 144A, 630.

195. **Orozco, J. D.** X-rays in Metallography, *Chemia* 39-40, 582; 41-42, 645 (1931); *Anales asocn. quím. Argentina* 22, 85B.

196. **Ott, E. and Cairns, R. W.** X-ray Studies of the Ni-O-H_2O System, *Z. Elektrochem.* 40, 286.

197. **Owen, E. A. and Iball, J.** X-ray Study of Aluminum-Zinc Alloys, *Phil. Mag.* 17, 433.

198. **Owen, E. A. and Pickup, L.** Parameter Values of Copper-Nickel Alloys, *Z. Krist.* 88, 116.

199. **Owen, E. A. and Yates, E. L.** The Thermal Expansion of the Crystal Lattices of Silver, Platinum and Zinc, *Phil. Mag.* 17, 113.

200. **Palacios, J. and Barasoain, J. A.** The Crystal Structure of Pyrophyllite, *Anales soc. españ. fís. quím.* 32, 271.

201. **Palacios, J. and Salvia, R.** The Crystalline Structure of Naphthazarin, *Anales soc. españ. fís. quím.* 32, 49.

202. **Parthasarathy, S.** X-ray Diffraction in Liquid Mixtures I, *Phil. Mag.* 18, 90.

203. **Patterson, A. L.** A Fourier Series Method for the Determination of the Components of Interatomic Distances in Crystals, *Phys. Rev.* 46, 372.

204. **Pauling, L. and Huggins, M. L.** Covalent Radii of Atoms and Interatomic Distances in Crystals Containing Electron-pair Bonds, *Z. Krist.* 87, 205.

205. **Pauling, L. and Neuman, E. W.** The Crystal Structure of Binnite and the Chemical Composition and Structure of Minerals of the Tetrahedrite Group, *Z. Krist.* 88, 54.

206. **Pauling, L. and Sherman, J.** Structure of the Carboxyl Group II. Crystal Structure of Basic Beryllium Acetate, *Proc. Natl. Acad. Sci.* 20, 340.

207. **Pauling, L. and Weinbaum, S.** The Structure of Calcium Boride, *Z. Krist.* 87, 181. 208. The Crystal Structure of Enargite, *ibid.* 88, 48.

209. **Perlitz, H.** The Structure of the Intermetallic Compound, Au_2Pb, *Acta Commentationes Univ. Tartu* **XXVIIA,** No. 11. 209a. The Crystal Structure of the Intermediate Phase of Au_2Pb, *Keemiateated* 2, 11.

210. **Pfister, H. and Wiest, P.** The Effect of Nickel Additions on Solubility and Precipitation in the System Silver-Copper, *Metallwirtschaft* 13, 317.

211. **Phillips, A. and Brick, R. M.** Effect of Quenching Strains on Lattice Parameter and Hardness Values of High-purity Aluminum-Copper Alloys, *Am. Inst. Min. Met. Eng., Inst. Metals Div., Tech. Pub.* No. 563.

212. **Pietsch, E. and Lehl, H.** Formation of Metallic Hydrides by Atomic Hydrogen II. The System Tantalum-Hydrogen, *Kolloid-Z.* 68, 226.

213. **Pohland, E.** A Handy X-ray Vacuum Camera for any Low Temperature, *Z. physik. Chem.* 26B, 238.

Year 1934

214. **Pope, W. J.** The Stacking of Spheres, *J. Soc. Chem. Ind.* 53, *Chem. Ind.* 361.

215. **Posener, L.** Extension of the Dynamical Theory of X-ray Interference, *Ann. Physik* 19, 849.

216. **Posnjak, E. and Barth, T. F. W.** Notes on Some Structures of the Ilmenite Type, *Z. Krist.* 88, 271.

217. **Powell, H. M. and Crowfoot, D.** The Crystal Structures of Dimethyl Thallium Halides, *Z. Krist.* 87, 370.

218. **Prins, J. A.** X-ray Diffraction in Cork, *Physica,* 1, 752.

219. **Ramdohr, P.** Nordenskiöldine from a Cassiterite Deposit, *Neues Jahrb. Mineral. Geol. Beilage-Bd.* 68A, 288.

220. **Randall, J. T.** "The Diffraction of X-rays and Electrons by Amorphous Solids, Liquids and Gases," London (1934).

221. **Regler, F.** The Relationship between the Thermal and Mechanical Loosening of Atomic Bonds in Metals, *Ann. Physik.* 19, 637. 222. Danger of Fracture and X-ray Diffraction, *Metallwirtschaft* 13, 427. (See 1934, 158.)

223. **Renninger, M.** Studies on the Reflection of X-rays by Rock Salt, *Z. Krist.* 89, 344. 224. X-ray Study of Rock Salt. "Ideally" Reflecting Rock Salt, *Naturwiss.* 22, 334.

225. **Riedmiller, R.** X-ray Investigations of Thin Nickel Sheets, *Ann. Physik* 20, 377.

226. **Ritter, G. J. and Stillwell, C. W.** Rate of Formation of the Crystalline Structure of Wood Fibers, *Paper Trade J.* 98, No. 22, 37.

227. **Robertson, J. M.** X-ray Analysis of the Crystal Structure of Dibenzyl I. Experimental and Structure by Trial, *Proc. Roy. Soc. (London)* 146A, 473. 228. Orientation of Molecules in p-Benzoquinone Crystals by X-ray Analysis, *Nature* 134, 138. 229. Shape of the Dibenzyl Molecule, *ibid.* 134, 381. 229a. The Space Group of Resorcinol, $C_6H_6O_2$, *Z. Krist.* 89, 518.

230. **Robertson, R., Fox, J. J. and Martin, A. E.** Two Types of Diamond, *Phil. Trans. Roy. Soc. London* 232A, 463.

231. **Rogozinski, A.** Focusing Method for X-ray Crystal Analysis, *Compt. rend.* 198, 953.

232. **Rooksby, H. P. and Chirnside, R. C.** The Formation of Basic Copper Chloride and its Identity with Atacamite, *J. Soc. Chem. Ind.* 53, *Trans. Communications* 33T.

233. **Rossi, A.** Crystal Structure of Lanthanum, Cerium and Praseodymium Hydrides, *Nature* 133, 174.

234. **Rossi, A. and Iandelli, A.** The Crystalline Structure of the Compounds $LaMg_3$, $CeMg_3$ and $PrMg_3$, *Rendiconti accad. Lincei* 19, 415.

235. **Saini, H. and Mercier, A.** Thermal Expansion of Sodium Nitrate Determined with the Help of X-rays, *Helv. Phys. Acta* 7, 267.

236. **Sakurada, I. and Hutino, K.** Ring Fiber Structure and Orientation of Micelles in Films as Shown by X-rays, *Sci. Pap. Inst. Phys. Chem. Research (Tokyo)* 24, 193.

237. **Schiff, K.** The Crystal System and Lattice Constants of Anhydrous Zinc Sulfate, *Z. Krist.* 87, 379.

238. **Schmid, E. and Siebel, G.** Alternating-torsion Tests on Magnesium Crystals, *Metallwirtschaft* 13, 353. 238a. Precipitation in Supersaturated Light-metal Alloys, *ibid.* 13, 765.

239. **Schmidt, W. and Doan, G. E.** Crystal Structure as a Guide in the Working of Magnesium Alloys, *Metals and Alloys* 5, 149.

240. **Schulze, G. E. R.** The Crystal Structure of BPO_4 and $BAsO_4$, *Z. physik. Chem.* 24B, 215. 240a. Crystal Form and Space Lattice of ZrF_4 and HfF_4, *Z. Krist.* 89, 477.

241. **Schwarz, E.** A Simple Camera for X-ray Structure Analysis of Coarse Crystalline Materials, *Physik. Z. Sowjetunion* 5, 443.

242. **Sederman, V. G.** Cu_2Mg Phase in the Copper-Magnesium System, *Phil. Mag.* 18, 343.

243. **Seifert, H.** Geochemical Masking in Anomalous Mixed Crystals, *Tschermaks Mineral. Petrog. Mitt.* 45, 191.

244. **Sisson, W. A.** X-ray Analysis of Textile Fibers II. Experimental Methods; Single-fiber Studies; Adsorption Effects; Fiber Decomposition; Oxidized Cellulose and Fiber Structure, *Textile Research* 4, 286.

245. **Sisson, W. A. and Clark, G. L.** Fluting in Annealed Sheet Steel and its Elimination, *Metals and Alloys* 5, 103.

Year 1934

246. **Skerl, A. C. and Bannister, F. A.** Lusakite, a Cobalt-bearing Silicate from Northern Rhodesia, *Mineralog. Mag.* 23, 598.

247. **Sommerfeldt, E.** The Relations between Crystal Lattice and Atomic Chemistry with Respect to the Periodic System of the Elements, *Centr. Mineral. Geol.* 1934A, 33.

248. **Šplíchal, J. and Cabicar, F.** X-ray Study of Transformations in Nickel-Chromium Steel, *Coll. Czechoslov. Chem. Communications* 6, 251.

249. **Staub, H.** Study of the Dielectric Properties of Rochelle Salt by X-rays, *Helv. Phys. Acta* 7, 3. 249a. Detection of the Internal Electric Field of Rochelle Salt by X-rays, *Physikal Z.* 35, 720.

250. **Staudinger, H.** The Structure of High-Molecular Organic Compounds, *Naturwiss.* 22, 65. 251. Highly Polymerized Compounds XCII. Constitution of Cellulose, *Cellulosechem.* 15, 53.

252. **Stewart, G. W.** The Present State of the Study of the Nature of Liquid Structure by Diffraction of X-rays, *Kolloid-Z.* 67, 130. 253. The Structure of n-Alcohol Solutions of Lithium Chloride, *J. Chem. Phys.* 2, 147. 254. Comparison of X-ray Diffraction Curves of Water and Deuterium Oxide at 25°, *ibid.* 2, 558.

255. **Stillwell, C. W. and Jukkola, E. E.** The Crystal Structure of NdAl, *J. Am. Chem. Soc.* 56, 56.

256. **Strada, M.** Investigations on the Structure of Pseudohalogens and Their Compounds I. Thallium Thiocyanate, *Gazz. chim. ital.* 64, 400. 256a. The Crystalline Structure of Thallium Cyanide, *Rendiconti accad. Lincei,* 19, 809.

257. **Strock, L. W.** Crystal Structure of High Temperature Silver Iodide α-AgI, *Z. physik. Chem.* 25B, 441.

258. **Tamaru, K. and Ôsawa, A.** Equilibrium Diagram of the System: Nickel-Zinc, *Bull. Inst. Phys. Chem. Research (Tokyo)* 13, 125.

259. **Tammann, G. and Bandel, G.** Heat Content and Specific Volume of Iron-Carbon Alloys, *Arch. Eisenhüttenw.* 7, 571.

260. **Tarschisch, L., Titow, A. T. and Garyanow, F. K.** An X-ray Investigation of $MgZn_2$, *Physik. Z. Sowjetunion* 5, 503.

261. **Taylor, W. H.** The Nature and Properties of Aluminosilicate Framework Structures, *Proc. Roy. Soc. (London)* 145A, 80.

262. **Taylor, W. H., Darbyshire, J. A. and Strunz, H.** An X-ray Investigation of the Feldspars, *Z. Krist.* 87, 464.

263. **Tilley, C. E.** Hydrocalumite, a New Mineral from Scawt Hill, County Antrim, *Mineralog. Mag.* 23, 607.

264. **Tomonari, T.** Cellulose LII. Method of Reaction of Cellulose 4. The Mechanism of the Denitration of Nitrocellulose, *Z. Elektrochem.* 40, 207.

265. **Trillat, J. J.** Nitrocellulose Films and their Polymorphism, *J. chim. phys.* 31, 125. 266. Researches on the Structure of the Fatty Esters of Cellulose, *J. phys. rad.* 5, 207. 267. Structure of Cellulosic Compounds. New Results Obtained by X-rays and the Diffraction of Electrons, *Chim. et ind.* Spec. No. 175.

268. **Trogus, C. and Hess, K.** Cellulose LII. Method of Reaction of Cellulose 3. The Formation of Intermediate Products in the Nitration of Cellulose and Their Relation to the Stability of Nitration Products, *Z. Elektrochem.* 40, 193. 269. X-ray Behavior of Sodium Cellulose II on Washing with Dilute Caustic Soda and on Dehydration, *Cellulosechem.* 15, 1.

270. **Trzebiatowski, W.** Hot-press Experiments with Highly Dispersed Metallic Powders III, *Z. physik. Chem.* 169A, 91. 271. Solidification in Pressed Metal Powders, *ibid.* 24B, 75.

272. **Vegard, L.** Structure of the β-Form of Solid Carbon Monoxide, *Z. Physik* 88, 235.

273. **Waldbauer, L. and McCann, D. C.** Cesium Nitrate and the Perovskite Structure, *J. Chem. Phys.* 2, 615.

274. **Waldbauer, L., McCann, D. C. and Tuleen, L. F.** Anhydrous Sodium Carbonate for Standardization, *Ind. Eng. Chem., Anal. Ed.* 6, 336.

275. **Ward, H. K.** An X-ray Study of the Structure of Liquid Benzene, Cyclohexane and Their Mixtures, *J. Chem. Phys.* 2, 153.

276. **Warren, B. E.** X-ray Diffraction Study of Carbon Black, *J. Chem. Phys.* 2, 551. 277. The Diffraction of X-rays in Glass, *Phys. Rev.* 45, 657. 278. Identification of Crystalline Substances by Means of X-rays, *J. Am. Ceram. Soc.* 17, 73. 279. X-ray Determination of the Structure of Glass, *ibid.* 17, 249.

Year 1934

280. Warren, B. E. and Gingrich, N. S. Fourier Integral Analysis of X-ray Powder Patterns, *Phys. Rev.* **46,** 368.

281. Wartmann, F. S. and Thompson, A. J. Progress Reports—Metallurgical Division 3. Studies in the Metallurgy of Copper. Preparation and Properties of Copper Ferrite, *Bur. Mines, Rept. of Investigations* **No.** 3228, 15.

282. Wassermann, G. Transformation of β-Aluminum Bronze, *Metallwirtschaft* **13,** 133.

283. Weigle, J. and Saini, H. The Thermal Expansion of Calcite, *Helv. Phys. Acta* **7,** 257.

284. Weiser, H. B. and Milligan, W. O. X-ray Studies on the Hydrous Oxides IV. Titanium Dioxide, *J. Phys. Chem.* **38,** 513.

285. Welo, L. A. and Baudisch, O. Ferromagnetism in the Oxide Obtained by Dehydration of γ-Ferric Oxide Hydrate, *Phil. Mag.* **17,** 753.

286. West, C. D. On the High-temperature Modification of CsCl, *Z. Krist.* **88,** 94. **287.** The Crystal Structures of Some Alkali Hydrosulfides and Monosulfides, *ibid.* **88,** 97. **288.** The Structure and Twinning of AgCN Crystals, *ibid.* **88,** 173. **289.** The Crystal Structure of Hexamethylethane and of Cubic Hexachloroethane, *ibid.* **88,** 195. **290.** Crystal Structures of Some Hydrated Compounds, *ibid.* **88,** 198. **291.** Orientation of Crystallites in the Ignition Products of $Mg(OH)_2$ and $Ca(OH)_2$, *Am. Mineral.* **19,** 281.

292. West, C. D. and Peterson, A. W. The Crystal Structure of $AuAl_2$, *Z. Krist.* **88,** 93.

293. Wever, F. X-ray Investigation of the Fine-structure in Technical Problems, *Arch. Eisenhüttenw.* **7,** 527.

294. Wheeler, T. S. Madelung Constants for Some Cubic Lattices, *Phil. Mag.* **17,** 1058.

295. Willott, W. H. and Evans, E. J. X-ray Investigation of the Arsenic-Tin System of Alloys, *Phil. Mag.* **18,** 114.

296. Wilson, D. A. and Ott, E. X-ray Study of the n-Aliphatic Alcohols $C_{10}H_{21}OH$ to $C_{18}H_{37}OH$, *J. Chem. Phys.* **2,** 231. **297.** Calculation of the Intensities of Reflection of a Series of n-Aliphatic Alcohols, *ibid.* **2,** 239.

298. Wilson, J. E. and Thomassen, L. X-ray Line Broadness of Metals and Alloys and its Relation to High-temperature Stability, *Trans. Am. Soc. Metals* **22,** 769.

299. Wolf, M. An Investigation of the Dihydrazide Molecule by Means of X-rays, *Physica* **1,** 417.

300. Wollan, E. O. and Compton, A. H. The Appearance of Atoms as Determined by X-ray Scattering, *J. Opt. Soc. Am.* **24,** 229.

301. Wood, W. A. Latent Energy Due to Lattice Distortion of Cold-worked Copper, *Phil. Mag.* **18,** 495.

302. Würstlin, F. Structure Determination of p-Azoxyanisole, *Z. Krist.* **88,** 185.

303. Wyckoff, R. W. G. and Corey, R. B. Spectrometric Measurements on Hexamethylene Tetramine and Urea, *Z. Krist.* **89,** 462.

304. Zachariasen, W. H. The Crystal Lattice of Boric Acid, *Z. Krist.* **88,** 150. **305.** Note on the Structure of the Trithionate Group, *J. Chem. Phys.* **2,** 109. **305a.** The Crystal Lattice of Oxalic Acid Dihydrate and the Structure of the Oxalate Radical, *Z. Krist.* **89,** 442. **305b.** The Atomic Arrangement in Potassium Trithionate Crystals and the Structure of the Trithionate Radical, *ibid.* **89,** 529.

306. Zachariasen, W. H. and Mooney, R. C. L. The Atomic Arrangement in Ammonium and Cesium Persulfates and the Structure of the Persulfate Group, *Z. Krist.* **88,** 63. **307.** The Structure of the Hypophosphite Group as Determined from the Crystal Lattice of Ammonium Hypophosphite, *J. Chem. Phys.* **2,** 34.

308. Ziegler, P. F. and Clark, G. L. The X-ray in the Study of the Catgut Ligature, *Surgery, Gynecology and Obstetrics* **58,** 578.

309. Zintl, E., Harder, A. and Dauth, B. Lattice Structure of the Oxides, Sulfides, Selenides and Tellurides of Lithium, Sodium and Potassium, *Z. Elektrochem.* **40,** 588.

310. Zintl, E. and Schneider, A. Lattice Structure of the Lithium-Cadmium Alloys, *Z. Elektrochem.* **40,** 107.

311. Zwicky, F. The Physics of Crystals I, *Rev. Mod. Physics* **6,** 193.

312. Alexander, E. Remarks on Systems of One-dimensional Space Groups, *Z. Krist.* **89,** 606.

313. Bakhmetev, E. F. X-ray Determination of the Structure of $FeAl_3$, *J. Exptl. Theoret. Phys.* (*U.S.S.R.*) **4,** 292. **313a.** X-ray Determination of the Structure of $FeAl_3$, *Z. Krist.* **89,** 575.

Year 1934

314. **Berg, W. F.** Laue Diagrams of Deformed Crystals, *Z. Krist.* **89**, 587.

315. **Borchert, W. and Ehlres, J.** Application of J. Leonhardt's Method for Orienting Laue Diagrams of Crystals of Unknown Setting to the Investigation of Phosphor-Nickel-Iron Deposits in Kamacite, *Z. Krist.* **89**, 553.

316. **Braekken, H. and Scholten, W.** The Crystal Structure of Mercuric Chloride, *Z. Krist.* **89**, 448.

317. **Brentano, J. and Baxter, A.** Anomalous Scattering of X-rays in the Neighborhood of the L Absorption Edge, *Z. Physik* **89**, 720.

318. **Brockway, L. O.** The Crystal Structure of Stannite, *Z. Krist.* **89**, 434.

319. **Bruni, G. and Ferrari, A.** Isomorphism of Compounds of Elements of Various Valences, *Z. Krist.* **89**, 499.

320. **Buckley, H. E.** On the Mosaic Structure in Crystals, *Z. Krist.* **89**, 221.

321. **Colby, M. Y. and Harper, J. P.** A Note on the Density and Crystal Structure of Sodium Carbonate Monohydrate, *Z. Krist.* **89**, 191.

322. **Colby, M. Y. and Harris, S.** An X-ray Study of a Long x-cut Quartz Crystal Vibrating under the Transverse Piezoelectric Effect, *Phys. Rev.* **46**, 445.

323. **Donnay, J. D. H., Tunell, G. and Barth, T. F. W.** Various Modes of Attack in Crystallographic Investigation, *Am. Mineral.* **19**, 437.

324. **Ehrenberg, W.** Atom Factor Determination for Metallic Beryllium, *Z. Krist.* **89**, 185.

325. **Engel, G.** The Crystal Structure of Some Hexachloro Salts, *Centr. Mineral. Geol.* **1934A**, 285.

326. **Farr, W. K. and Sisson, W. A.** X-ray Diffraction Patterns of Cellulose Particles and Interpretations of Cellulose Diffraction Data, *Contrib. Boyce Thompson Inst.* **6**, 315.

327. **Forestier, H. and Guiot-Guillain, G.** New Ferromagnetic Variety of Ferric Oxide, *Compt. rend.* **199**, 720.

328. **Fricke, R. and Ackermann, P.** Heat Content and Lattice Structure of Active Ferric Oxide, *Z. Elektrochem.* **40**, 630.

329. **Glocker, R.** X-rays and Technical Research, *Z. tech. Physik* **15**, 421.

330. **Gossner, B. and Neff, H.** The Crystals of the Hydrochloride, Hydrobromide and Hydroiodide of Methyl Ephedrine. A Contribution to the Knowledge of Crystallographic Relationships between d,l-Compounds and their Components, *Z. Krist.* **89**, 417.

331. **Halla, F. and Tompa, H.** The State of Sodium Dissolved in Sodium Hydroxide Melts, *Z. anorg. Chem.* **219**, 321.

332. **Harker, D.** The Crystal Structure of the Mineral Tetradymite, *Z. Krist.* **89**, 175.

333. **Harvey, G. G.** The Effect of Pressure on the Intensity of X-rays Scattered from Nitrogen at Small Angles, *Phys. Rev.* **46**, 441.

334. **Hendricks, S. B.** Cholesteryl Salicylate, *Z. Krist.* **89**, 427.

335. **Hermann, L. and Sachs, G.** Crystal Alignment in Drawn Brass Cups, *Metallwirtschaft* **13**, 745.

336. **James, R. W.** The Intensities of X-ray Spectra and the Imperfections of Crystals, *Z. Krist.* **89**, 295.

336a. **Katzoff, S.** X-ray Studies of the Molecular Arrangement in Liquids, *J. Chem. Physics.* **2**, 841.

337. **Laves, F.** A Manganese-Silicon Alloy of the Tungsten Type (A2-Type), *Z. Krist.* **89**, 189. 338. The Crystal Structure of Boron Carbides, *Nachr. Ges. Wiss. Göttingen, Math.-phys. Kl., Fachgr. IV,* **1**, No. 5, 57.

339. **Laves, F. and Löhberg, K.** The Crystal Structure of Intermetallic Compounds of the Formula AB_2, *Nachr. Ges. Wiss. Göttingen, Math.-phys. Kl., Fachgr. IV,* **1**, No. 6, 59.

340. **Laves, F., Löhberg, K. and Rahlfs, P.** The Isomorphism of Mg_3Al_2 and α-Manganese, *Nachr. Ges. Wiss. Göttingen, Math.-phys. Kl., Fachgr. IV,* **1**, No. 7, 67.

340a. **Linitz'kii, V.** X-ray Diffraction through Crystal Lattices and X-ray Structural Analysis, *Ukrain. Khem. Zhur.* **9**, *Tech. Pt.* 46.

340b. **Mack, E., Jr.** Structure of Rubber and the Mechanism of Elastic Stretching, *J. Am. Chem. Soc.* **56**, 2757.

341. **Morral, F. R.** Constitution of Iron-rich Iron-Aluminum-Carbon Alloys, *J. Iron Steel Inst. (London) Adv. copy* **No. 8.**

342. **Neugebauer, T. and Gombás, P.** Calculation of the Lattice Constant of Potassium Chloride, *Z. physik* **89**, 480.

Year 1934

343. **Neuhaus, A.** Crystallographic and Refractometric Investigations of α-Follicular Hormone, *Z. Krist.* 89, 505.

344. **Nishikawa, S., Sakisaka, Y. and Sumoto, I.** X-ray Investigation of the Mode of Vibration of Piezoelectric Quartz Plates, *Sci. Pap. Inst. Phys. Chem. Research (Tokyo)* 25, 20.

345. **Nowacki, W.** Survey of New Structure Determinations of the Compounds AB_3, *Z. Krist.* 89, 85.

346. **Offner, F.** A Redetermination of the Parameter for Hauerite, *Z. Krist.* 89, 182.

347. **Pabst, A.** The Crystal Structure of Sulphohalite, *Z. Krist.* 89, 514.

347a. **Palacios, J. and Galloni, E. E.** The Crystalline Structure of Calcium Sulfate Dihydrate (Gypsum), *Anales soc. españ. fís. quím.* 32, 779.

347b. **Reinicke, R.** The Universal Meaning of the Cubic Face-centered Lattice Structure for the Causal Comprehension of Previously Unknown Relationships, *Z. physik. Chem.* 27B, 28.

348. **Reininger, H.** X-ray Analysis as an Aid to the Electroplating Industry I. Fundamentals of X-ray Analysis, *Metallwaren-Ind. u. Galvano-Tech.* 32, 260, 283, 360, 383, 409, 427.

348a. **Saito, G.** The Swelling of Cellulose in Alkali VIII. General Discussion, *J. Soc. Chem. Ind., Japan,* 37, *Suppl. binding* 642.

349. **Samans, C. H.** An X-ray Study of Orientation Changes in Cold Rolled Single Crystals of α-Brass, *Am. Inst. Min. Met. Eng., Inst. Metals Div., Tech. Pub.* No. 579.

350. **Schmid, E.** Determination of Structure as an Aid in Alloy Research, *Berg- u. Hüttenmännisches Jahrb.* 82, 126.

351. **Schmid, E. and Wassermann, G.** The System Aluminum-Zinc, *Z. Metallkunde* 26, 145.

352. **Seljakow, N. J. and Sows, E. I.** A Method for Graphically Indexing Rotation Crystal Photographs, *Z. Krist.* 89, 601.

353. **Sirk, H.** The Influence of a Magnetic Field on the Scattering of X-rays in Liquids, *Z. Physik* 89, 129.

354. **Šplíchal, J.** Changes in the Structure of Hardened and Annealed Steels, *Chem. Listy* 28, 225.

354a. **v. Stackelberg, M.** The Structural Principle of Carbides, Silicides, Nitrides and Phosphides of Electropositive Metals, *Z. physik. Chem.* 27B, 53.

354b. **v. Stackelberg, M. and Quatram, F.** The Structure of Beryllium Carbide, *Z. physik. Chem.* 27B, 50.

354c. **v. Stackelberg, M. and Schnorrenberg, E.** The Structure of Aluminum Carbide, *Z. physik. Chem.* 27B, 37.

355. **Torrance, C. C.** Hartree Fields of Carbon, *Phys. Rev.* 46, 388.

356. **Trousil, Z.** X-ray Analysis of Microcrystalline Substances and its Precision, *Chem. Obzor* 9, 126, 144, 161.

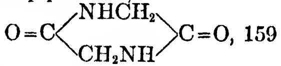
357. **Vegard, L. and Kloster, A.** Gold-Copper Alloys Especially at High Temperatures, *Z. Krist.* 89, 560.

358. **Warren, B. E. and Hill, C. F.** The Structure of Vitreous BeF_2, *Z. Krist.* 89, 481.

359. **Wesselowski, W. S. and Wassiliew, K. W.** X-ray Investigation of Disperse Structures of Various Kinds of Graphite, *Z. Krist.* 89, 156. 360. Twin Formation in Graphite Crystals, *ibid.* 89, 494.

361. **Ziegler, G. E.** The Crystal Structure of Lithium Sulfate Monohydrate, *Z. Krist.* 89, 456.

362. **Zhdanov, G. S.** X-ray Analysis of the Structure Changes by Cold Deformation of Metals, *Zavodskaya Lab.* 3, 48, 156.



MEMORANDA

MEMORANDA

American Chemical Society

MONOGRAPH SERIES

PUBLISHED

No.

1. **The Chemistry of Enzyme Action (Revised Edition)**
   By K. George Falk.
2. **The Chemical Effects of Alpha Particles and Electrons (Revised Edition)**
   By Samuel C. Lind.
3. **Organic Compounds of Mercury**
   By Frank C. Whitmore.
4. **Industrial Hydrogen**
   By Hugh S. Taylor.
5. **Zirconium and Its Compounds**
   By Francis P. Venable.
6. **The Vitamins (Revised Edition)**
   By H. C. Sherman and S. L. Smith.
7. **The Properties of Electrically Conducting Systems**
   By Charles A. Kraus.
8. **The Origin of Spectra**
   By Paul D. Foote and F. L. Mohler.
9. **Carotinoids and Related Pigments**
   By Leroy S. Palmer.
10. **The Analysis of Rubber**
    By John B. Tuttle.
11. **Glue and Gelatin**
    By Jerome Alexander.
12. **The Chemistry of Leather Manufacture (Revised Edition)**
    By John A. Wilson. Vol. I and Vol. II.
13. **Wood Distillation**
    By L. F. Hawley.
14. **Valence and the Structure of Atoms and Molecules**
    By Gilbert N. Lewis.
15. **Organic Arsenical Compounds**
    By George W. Raiziss and Jos. L. Gavron.
16. **Colloid Chemistry (Revised Edition)**
    By The Svedberg.
17. **Solubility**
    By Joel H. Hildebrand.
18. **Coal Carbonization**
    By Horace C. Porter.
19. **The Structure of Crystals (Revised Edition)**
    By Ralph W. G. Wyckoff.
20. **The Recovery of Gasoline from Natural Gas**
    By George A. Burrell.
21. **The Chemical Aspects of Immunity (Revised Edition)**
    By H. Gideon Wells.
22. **Molybdenum, Cerium and Related Alloy Steels**
    By H. W. Gillett and E. L. Mack.

[*Continued*]

American Chemical Society

MONOGRAPH SERIES

PUBLISHED

No.
23. **The Animal as a Converter of Matter and Energy**
By H. P. Armsby and C. Robert Moulton.
24. **Organic Derivatives of Antimony**
By Walter G. Christiansen.
25. **Shale Oil**
By Ralph H. McKee.
26. **The Chemistry of Wheat Flour**
By C. H. Bailey.
27. **Surface Equilibria of Biological and Organic Colloids**
By P. Lecomte du Noüy.
28. **The Chemistry of Wood**
By L. F. Hawley and Louis E. Wise.
29. **Photosynthesis**
By H. A. Spoehr.
30. **Casein and Its Industrial Applications**
By Edwin Sutermeister. To be revised by F. L. Browne.
31. **Equilibria in Saturated Salt Solutions**
By Walter C. Blasdale.
32. **Statistical Mechanics as Applied to Physics and Chemistry**
By Richard C. Tolman.
33. **Titanium**
By William M. Thornton, Jr.
34. **Phosphoric Acid, Phosphates and Phosphatic Fertilizers**
By W. H. Waggaman.
35. **Noxious Gases**
By Yandell Henderson and H. W. Haggard.
36. **Hydrochloric Acid and Sodium Sulfate**
By N. A. Laury.
37. **The Properties of Silica**
By Robert B. Sosman.
38. **The Chemistry of Water and Sewage Treatment**
By Arthur M. Buswell.
39. **The Mechanism of Homogeneous Organic Reactions**
By Francis O. Rice.
40. **Protective Metallic Coatings**
By Henry S. Rawdon. To be revised by R. M. Burns.
41. **Fundamentals of Dairy Science (Revised Edition)**
By Associates of Rogers.
42. **The Modern Calorimeter**
By Walter P. White.
43. **Photochemical Processes**
By George B. Kistiakowsky.
44. **Glycerol and the Glycols**
By James W. Lawrie.
45. **Molecular Rearrangements**
By C. W. Porter.

[*Continued*]

American Chemical Society

MONOGRAPH SERIES

PUBLISHED

No.

46. **Soluble Silicates in Industry**
    By James G. Vail.
47. **Thyroxine**
    By E. C. Kendall.
48. **The Biochemistry of the Amino Acids**
    By H. H. Mitchell and T. S. Hamilton.
49. **The Industrial Development of Searles Lake Brines**
    By John E. Teeple.
50. **The Pyrolysis of Carbon Compounds**
    By Charles D. Hurd.
51. **Tin**
    By Charles L. Mantell.
52. **Diatomaceous Earth**
    By Robert Calvert.
53. **Bearing Metals and Bearings**
    By William M. Corse.
54. **Development of Physiological Chemistry in the United States**
    By Russell H. Chittenden.
55. **Dielectric Constants and Molecular Structure**
    By Charles P. Smyth.
56. **Nucleic Acids**
    By P. A. Levene and L. W. Bass.
57. **The Kinetics of Homogeneous Gas Reactions**
    By Louis S. Kassel.
58. **Vegetable Fats and Oils**
    By George S. Jamieson.
59. **Fixed Nitrogen**
    By Harry A. Curtis.
60. **The Free Energies of Some Organic Compounds**
    By G. S. Parks and H. M. Huffman.
61. **The Catalytic Oxidation of Organic Compounds in the Vapor Phase**
    By L. F. Marek and Dorothy A. Hahn.
62. **Physiological Effects of Radiant Energy**
    By H. Laurens.
63. **Chemical Refining of Petroleum**
    By V. Kalichevsky and B. A. Stagner.
64. **Therapeutic Agents of Quinoline Group**
    By W. F. Von Oettingen.
65. **Manufacture of Soda**
    By T. P. Hou.
66. **Electrokinetic Phenomena and Their Application to Biology and Medicine**
    By H. A. Abramson.
67. **Arsenical and Argentiferous Copper**
    By J. L. Gregg.
68. **Nitrogen System of Compounds**
    By Edward C. Franklin.

American Chemical Society

MONOGRAPH SERIES

IN PREPARATION

Piezo-Chemistry
By L. H. Adams.

Water-Softening
By A. S. Behrman.

The Biochemistry of the Fats and Related Substances
By W. R. Bloor.

Polymerization
By R. E. Burk.

Absorptive Carbon
By N. K. Chaney.

Sulfuric Acid Manufacture
By Andrew M. Fairlie.

Surface Energy and Colloidal Systems
By W. D. Harkins and T. F. Young.

The Corrosion of Alloys
By Robert J. McKay.

Significance of Manganese, Iron and Aluminum to Soil Acidity and Plant Life
By Forman T. McLean.

Physical and Chemical Properties of Glass
By Geo. W. Morey.

Metabolic Action of Insulin
By John R. Murlin.

Acetylene
By J. A. Nieuwland.

Furfural
By F. N. Peters, Jr., and H. J. Brownlee.

Carbon Dioxide
By Elton L. Quinn and Charles L. Jones.

Aliphatic Sulfur Compounds
By E. Emmet Reid.

The Chemistry of Intermediary Metabolism
By Wm. C. Rose.

Electrical Precipitation of Suspended Particles from Gases
By W. A. Schmidt and Evald Anderson.

Mineral Metabolism
By A. T. Shohl.

Precise Electric Thermometry
By W. P. White and E. F. Mueller.

Ergosterol
By A. Windaus.

Measurement of Particle Size and Its Application
By L. T. Work.